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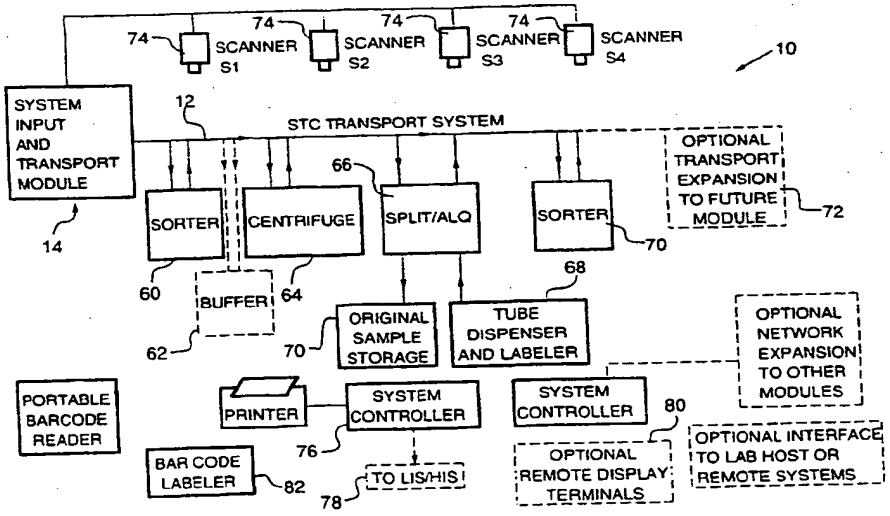

(57) Abstract

A system (10) for transporting blood specimens for processing. The system includes mechanism for carrying each blood specimen to be processed and a plurality of modules (14, 60, 62, 64, 66, 68, 70) each of which performs a process upon the specimens as the specimens pass through the modules (14, 60, 62, 64, 66, 68, 70). The modules (14, 60, 62, 64, 66, 68, 70) together, define a path (12) along which the specimens move through the system (10). A drive is provided to move specimen transport carriages from module to module. The system includes a sorter module (60) for segregating blood specimens of like characteristics based upon identifying indicia applied to specimen tubes carrying the blood specimens.

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SYSTEM FOR TRANSPORTING, CLASSIFYING, AND SORTING BLOOD SPECIMENS

Technical Field

The present invention deals broadly with the field of medical technology. More specifically, however, it deals with the field of automated blood specimen handling. A preferred embodiment of the invention deals with such a system which includes at least one sorter module, a centrifuge module, and a module for aliquotting portions of a blood specimen from one specimen tube into a plurality of such tubes. In that embodiment, the sorter module effects segregation of specimens based upon barcode information applied to the specimens tubes carrying the blood specimens, and distribution of like specimens to designated geographic location.

Background of the Invention

In many countries of the world, the health care industry is one of the largest, if not the largest, industry. In spite of the fact that life expectancies today are considerably higher than they were decades ago, the health care industry continues to burgeon. In fact, many will argue that the growth of the industry is, in fact, responsible for the lengthening of life expectancies.

As society has become more complex and sophisticated, an ever increasing number of maladies have resulted. Illustrative is the plague of acquired immune deficiency syndrome (AIDS) which has become rampant over the last decade.

Because of the potentially lethal results of various of the maladies, efficient detection, diagnosis, and treatment are essential. Various types of diagnostic tests have been developed for different maladies. In view of the wide range of diagnostic testing methods and devices available in the health care industry today and the growing reliance of physicians upon the test methods and devices, laboratory services are in heavy demand.

The generation of such a demand and the resultant increasing competition mandates increased productivity, better quality, and lower cost.

Before being subjected to actual quantitative analysis, blood specimens are sent through a series of front-end specimen processing steps. These include receiving the specimens and accessioning the specimens, sorting the specimens, centrifuging the specimens, splitting the specimens, and labelling the specimen tubes with the appropriate identifying indicia. Front-end processing and quantitative analysis represent a major time and labour component for all specimens entering a laboratory.

In view of these facts, the importance of time savings has come into focus. To this end, some attempts have been made to accomplish automation of specimen handling. In recent years, some quantitative testing has been successfully automated. Front-end specimen processing, however, has not, as of yet, been addressed as an integrative, automated process. Automating the front-end testing phase would result in significant gains in productivity. Additionally, costs would be considerably lowered.

Other factors mitigate in favour of automation. In view of the potential health risk to health care workers because of potential contamination by specimens, employees are increasingly reluctant to manually handle blood products. Further, in view of the repetitive nature of the tasks involved in front-end specimen processing, an increased possibility of transcription errors and other mistakes can result.

A number of very practical considerations also impinge upon the equation. The overall skill-set of employees doing this type of work is generally low. Further, undesirable work schedules and low pay result in a high turnover rate. As a result, retraining costs can be significant.

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It is to these problems and dictates of the prior art that the present invention is directed. It is a system which enables automated front-end specimen processing to be employed.

Summary of the Invention

The present invention is a system for transporting blood specimens. The specimens, when so transported, are processed in various manners. The system includes means for carrying each discrete blood specimen. A plurality of modules are employed for performing a corresponding number of pre-qualitative analysis processes upon the specimens. The modules, together, define a path along which the means carrying the blood specimens move through the system. Drive means are employed to move the carrying means from one module to another along the path defined by the module.

In a preferred embodiment, the system can include transport means for receiving each container carrying a blood specimen. Such transport means facilitate movement of the specimens through the system. It is intended that the transport means be provided with a window to expose identifying indicia applied to the means carrying the blood specimens.

In one assembly of the system, at least one sorter module is employed. Preferably, the system would, additionally, include a centrifuge module and a module for aliquotting portions of a blood specimen carried by one container into a plurality of containers.

Typically, the modules would be positioned adjacent one another. With such positioning, the modules would, together, define the path along which the carrying means transporting the blood specimens move through the system.

In a preferred construction of the system, blood specimens are carried in corresponding barcoded specimen tubes. In the preferred embodiment, such tubes

are received in transport devices, commonly referred to as "specimen transport carriers", each having a window to expose barcode information applied to the particular specimen tube.

The preferred sorter employs an input column for receiving a nested string of the transport devices which have the specimen tubes received therewithin. Each input column has a feed end and a singulation end. Means are adopted to move the transport devices along the input column from the feed end thereof to the singulation end thereof. Such means for moving the transport devices, it is envisioned, would comprise a belt drive mechanism.

The sorter also includes means for singulating a lead transport device presented at the singulation end of the input column, from the nested string of transport devices. Such means can include at least one ramped blade element which is disposed for reciprocal movement across the input column. When extended, the blade element would be inserted between the lead transport device presented at the singulation end of the input column and a second transport device immediately rearward of the lead transport device. Such insertion functions to effect denesting of the lead transport device from the rest of the nest.

The preferred sorter module also includes first conveyor means which intersect the input column proximate the singulation end thereof. Positioned along the length of the first conveyor means is a station in which barcode information applied to a specimen tube is read. In the preferred embodiment, the ramped blade element which effects denesting of the lead transport device in the input column from the rest of the nest also serves to urge that denested transport device onto the first conveyor means. That denested transport device is then conveyed by the first conveyor means to the station at which the barcode information applied to the specimen tube is read.

The sorter module also includes a plurality of output columns. Means are employed for depositing transport devices from the station at which barcode information is read into one of the output columns. The specific column in which the individual transport device is deposited depends upon the barcode information which is read. Typically, the means by which the transport devices are deposited into the output columns would comprise a second conveyor which can, in the preferred embodiment, be oriented generally parallel to the first conveyor means.

In the preferred embodiment also, means are provided at the barcode information reading station to effect rotation of the specimen tube positioned at the station while the transport device is held stationary. As a result of rotation of the specimen tube, barcode information will be made viewable through the window in the transport device, regardless of the initial rotational orientation of the specimen tube within the transport device at the time the transport device arrives at the station. It is envisioned that the means by which the specimen tube would be rotated would effect rotation of the tube through 360°. Multiple rotations can be effected if reading fails on the first rotation.

The present invention is thus an improved system for transporting blood specimens for processing. More specific features and advantages obtained in view of those features will become apparent with reference to the DETAILED DESCRIPTION OF THE INVENTION, appended claims, and accompanying drawing figures.

Brief Description of the Drawings

FIG. 1 is a schematic representation of the flow of blood samples through a preferred embodiment of the invention;

FIG. 2 is a perspective view of a specimen tube used in the system of FIG. 1;

FIG. 3 is a perspective view of the specimen tube in assembly with a specimen transport carrier;

FIG. 4 is a perspective view of a specimen transport carrier;

FIG. 5 is a perspective view of the subject of FIG. 4 rotated on its base 90° counter-clockwise thereof;

FIG. 6 is a front elevational view thereof;

FIG. 7 is a left side elevational view thereof;

FIG. 8 is a right side elevational view thereof;

FIG. 8a is a rear elevational view thereof;

FIG. 9 is a perspective view of an assembly of various modules into a system thereof;

FIG. 10 is a top plan functional diagram of a split/aliquot module assembly showing component layout thereof;

FIG. 11 is a front elevational mechanical schematic of an aliquoter assembly thereof in inversion/operation charge position;

FIG. 12 is a view similar to FIG. 11 in puncture position;

FIG. 13 is a view similar to FIG. 11 in inverted dispense position;

FIG. 14 is a schematic representation of a sorter module;

FIG. 15 is a multi-sheet top plan view of a sorter module comprising sub-assemblies common to module activities;

FIG. 16 is a front elevational view of FIG. 15;

FIG. 17 is a fragmentary left end elevational detail view of FIG. 16;

FIG. 18 is a fragmentary rear sectional view thereof taken generally along line 18-18 in FIG. 15;

FIG. 19 is a fragmentary perspective view of FIG. 15 on an enlarged scale and including specimen transport carriers;

FIG. 20 is a multi-sheet bottom plan view of sorter module;

FIG. 21 is a front elevational view of the tube rotation assembly;

FIG. 22 is a top plan view thereof;

FIG. 23 is a right side elevational view thereof;

FIG. 24 is a fragmentary view similar in part to FIG. 23 with parts shown in open position;

FIG. 25 is a fragmentary top plan view showing a photo diode assembly in association with the tube rotation assembly;

FIG. 26 is a fragmentary top plan view showing the infeed assembly junction with the transfer assembly;

FIG. 27 is a fragmentary front elevational view of the infeed assembly;

FIG. 28 is a front elevational view of the singulator/separator gate assembly located within the infeed assembly junction;

FIG. 29 is a left side elevational view thereof;

FIG. 30 is a fragmentary sectional elevation taken generally along line 30-30 in FIG 29;

FIG. 31 is a right side elevational view of the sorter module with some parts omitted and some parts in phantom to show a shuttle assembly and sorter;

FIG. 32 is a top plan view of a shuttle assembly;

FIG. 33 is a left side elevational view of FIG. 32;

FIG. 34 is a front elevational view of FIG. 32;

FIG. 35 is a sectional elevation taken generally along line 35-35 in FIG. 34;

FIG. 36 is a right side elevational detail of a carriage assembly shown in FIG. 31;

FIG. 37 is a front elevational view thereof;

FIG. 38 is a detail view of a portion of the sorter module shown in FIG. 31; and

FIG. 39 is a section on the line 39-39 of FIG. 14 showing further details of the sorter assembly.

General Arrangement

Referring therefore to the drawings and initially to Figures 1 and 9, an automated specimen handling system (ASH) generally indicated at 10 utilizes a transport system 12 to transfer samples between individual modules where individual operations may be performed upon the samples. It will be understood that the number of modules and their configuration will vary according to the particular applications, but that the transport system 12 provides a versatility to allow monitoring and handling of individual specimens on an automated basis. In the exemplified embodiment shown in Figures 1 through 9, the system includes a loader 14 which assembles specimens sealed within specimen tubes 16 into specimen tube carriers 18 for transport through the system 12.

The tubes 16 and carriers 18 are shown in more detail in Figures 2 through 8, where it will be seen that the carrier 18 includes a body 20 having a rectangular base 22 and head 24 interconnected by a generally cylindrical sleeve 26. The sleeve 26 defines a cylindrical bore 21 to receive the tube 16. An elongate slot 28 extends from the head 24 along the body 26 and terminates in the base 22. Each of the base 22 and head 24 includes a button 29 projecting from one of the faces 30 of the base 22 and head 24. An opposite face 32 on each of the base 22 and head 24 is formed with a rectangular recess 34 with a pair of resilient webs 36 extending across the recess 34. The webs 36 are configured to define an aperture to receive a respective one of the buttons 28 and resiliently hold it to connect a pair of the carriers 18 in seriatim.

The Specimen Tube Carrier

As can best be seen from Figures 7 and 8, rear face 38 of the head 24 is formed with a rectangular boss 40 that is received within an enlarged throat 42 formed at the upper end of the slot 28. A ledge 44 also projects rearwardly from the face 38 to be received within a shoulder 46 formed on the lower apex of the front face 48 of the head 24.

The rearwardly directed face 50 of the base 22 is also formed with a rectangular boss 52 which is dimensioned to be received within the lower portion of the slot 28 of an adjacent carrier 18. As such, a pair of carriers 18 may be nested with the rear face 38 abutting the forward face 48 of an adjacent carrier 18 and may also be connected laterally through interaction of the bosses 28 with the resilient webs 36. The base 22 also carries a pair of grooves 54,56 extending on the front and rear faces of the base 22 adjacent the bottom thereof.

The cylindrical bore 21 formed in the body 20 snugly receives the specimen tube 16 which has a label 58 located on its body. The label 58 carries bar encoded indicia which will be displayed at the slot 28 when the tube 16 is orientated so that the label 58 is aligned with the slot 28. Although the tube 16 is snugly received within the bore 21, it is free to rotate within the bore and therefore allow adjustment of the tube 16 to bring the label 58 into alignment with the slot 28.

The details of the carrier 18 and the tube 16 are more fully described in co-pending U.S. patent Application Serial Number 913,589 filed on July 14, 1992, the contents of which are incorporated herein by reference.

System Configuration

In the embodiment of the system shown in Figures 1 and 9, the loaded specimen tube carriers 18 are

transferred through the transport system 12 to a first sorter module 60. The sorter module 60 is controlled to perform a predetermined sorting process according to information encoded on the label 58 as will be described more fully below, the sorter 60 may deliver sorted specimen carriers 18 back to the transport system 12 or to a collection area at the front of the module 60 depending on the encoded information on label 58.

A buffer unit 62 is provided to temporarily hold surplus carriers 18 and supply them to a centrifuge 64 as required. The transport system 12 may also deliver carriers 18 either from the centrifuge or directly from the sorter to a splitter aliquot module 66 which receives the original specimen carrier 18, dispenses a predetermined amount of liquid from the tube 16 in the original specimen container 18 into empty new tubes 16 held within respective containers 18 retrieved from a storage area 68. The new tubes 16 have been labelled with appropriate labels 58 and are returned to the transport system 12 for further manipulation. The original tubes 16 and transport carriers 18 are deposited in a storage area 70 from where they can be removed at an appropriate time.

The transport system 12 delivers the new carriers 18 from the splitter aliquot 66 together with those carriers 18 that have by-passed the splitter aliquot to a sorter 70 similar to the sorter 60 used in the initial stages of the transport system 10. The sorter 70 manipulates the carriers 18 according to the barcoded information and delivers them into test or process related bins for distribution throughout the laboratory. Alternatively, as indicated in chain dot line, the sorter 70 may deliver carriers 18 to further modules indicated generally at 72 for further processing.

The movement of the carriers 18 through the transport system 12 is controlled by barcode scanners 74 that monitor the passage of the carriers and provide

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information regarding the progress of the tubes 16 within the carriers 18 to the system controller 76. The system controller controls operation of the individual modules, each of which will have appropriate sensing and data communication systems to interface with the controller 76 and may also interface to the laboratory and hospital information systems indicated at 78, or remote display terminals 80 and will control operation of a barcode labeller 82 to prepare labels 58 for the tubes 16.

Movement Through A Module

An overview of the operation of the transport system 12 may best be provided with reference to the aliquot module 66 shown schematically in Figure 10. The transport system 12 includes an input indexer 100 that extends through the module 66 to convey carriers 18 in the direction indicated by arrow A. The carriers 18 may also be provided as a nested series along an input column 102 that intersects the track 100. The input indexer 100 is intended to convey individual carriers 18 in spaced sequence to allow orderly manipulation of the individual carriers. Those carriers arriving at the modules 66 on the indexer 100 are already spaced and may proceed in an orderly fashion in the direction of arrow A. Nested columns of carriers 18 on the input column 102 are advanced to the intersection of the column 102 and indexer 100 where they are separated by a singulator 104 and integrated with carriers on the indexer 100. The singulator delivers an individual carrier 18 to the indexer 100 from where it is advanced to a barcode reading station 106 which reads the label 58 and identifies the particular specimen tube 16.

The carrier 18 is further advanced to a shuttle station 108 where it is transferred to a shuttle 110 to a pusher 112. The pusher 112 delivers the carrier 18 to the input of a star wheel 120 that rotates counter-clockwise to move the carrier 18 past a volume reader 122

that determines the volume of the contents of the tube 16 to a pickup point indicated at 124. The carrier 18 at the pickup point 124 is manipulated by an aliquotting engine 126 described in further detail below to transfer a portion of the contents to a new tube 16 in its associated carrier 18. The original carrier 18 is then transferred from the pickup point 124 to a discharge point 126 and onto a shuttle mechanism 128. The shuttle mechanism delivers the carrier 18 to the original sample storage device 70 for subsequent disposal.

The empty carriers 18 are delivered from the tube dispensing area 68 by an output star wheel 130 to a dispensing point 132. The aliquot engine 126 dispenses a portion of the contents of the original tube 16 into the new tube 16 and the star wheel 130 delivers the carrier 18 with the new tube 16 to the output 134. The carrier 18 is then integrated with the input indexer 100 and delivered either to the next output column 136 or transferred to a further module along the input indexer.

The Aliquotter

The aliquotting engine 126 is shown in further detail in Figures 11 through 13 and includes a carrier housing 138 that is rotatably mounted upon a shaft 140. The housing 138 carries a motor 142 that drives a screw thread 144 connected to a platform 146. The platform is guided by guide rods 148 for movement relative to the housing 138. The platform 146 is positioned to receive the carrier 18 at the pickup point 124 and upon operation of the motor 142 will elevate the platform 146 to move the tube 16 into engagement with a throquot 150. The throquot is essentially a canula having an enlarged radial collar 152 that is operable to allow discharge of the contents of the tube 16 upon application of pressurized air through the throquot. The throquot is described in further detail in U.S. patent application serial number _____ filed on _____.

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The throquot is delivered to the alliquottes on a track and held in the position indicated in Figure 11. The throquot 150 cooperates with a finger 154 secured to the housing 138 that has an aperture 156 to receive the body of the throquot 150. Collar 152 bears against the underside of the finger 154 to limit movement of the throquot so that upon energization of the motor 142 to elevate the platform 146, the throquot 150 is forced into the seal of the tube 16 and held against the finger 154. This is shown more fully in Figure 12.

The housing 138 is then rotated about the shaft 140 as shown in Figure 13, so that the throquot 150 pierces the seal of new tube 16 and the carrier 18 delivered by the star wheel 130 to the dispensing point 132. A predetermined volume of the contents of the old tube 16, based upon the reading obtained from the volume reader 122, may then be transferred into the new tube 16 located at the dispensing point 132 and the housing 138 returned to the initial position as shown in Figure 11. The old carrier 18 may then be dispensed through the shuttle 128 to the holding zone 70 and the new carrier 18 directed to the discharge 134.

The operation of the aliquot is shown in further detail in U.S. Patent No. _____ issued to Andronic.

The principals of operation of the mechanisms utilized in the splitter aliquoter module 66 to manipulate the carriers 18 are utilized in the sorter module 60 and are therefore best described with respect to the operation of that device. Before discussing the details of the individual mechanisms, an overview of the operation of the sorter module 60 will be provided so as to appreciate the interaction of the various mechanisms.

Sorter

To facilitate recognition of the common mechanisms and emphasise the versatility of the system

10, similar reference numerals for those used above with respect to Figure 10, will be used to denote like mechanisms with a suffix "A" added for clarity. It will of course be appreciated that the principals of operation of these mechanisms are similar but that the specific details of design may be varied according to the individual applications and the locations in which the mechanisms are to be utilized.

As shown in Figure 14, the sorter module 60 includes an input column 102A that delivers nested carriers 18 to a singulator 104A. The singulator 104A separates the carriers 18 and delivers them to the indexer 100A. The carriers 18 are transported to a barcode reading station 106A which verifies the contents of the tube 16 and determines the appropriate manipulation for it. The indexer 100A delivers the carrier 18 to a shuttle 110A. If the carrier 18 is simply to continue along the indexer 100A it continues past the shuttle 110A. However, if it is to be distributed into one of a number of output columns 136A the shuttle operates to transfer the carrier 18 to a pusher 164. The pusher carries the carrier 18 in a direction parallel to the indexer 100 under the control of a stopper drive motor 166 to the head of an appropriate column 136A as determined by the barcode scanner 106A. Once located at the head of the appropriate output column 136A, the pusher releases the carrier 18 and an insertion bar 168 located below the pusher engages the tubular body 26 and advances the carrier 18 into the appropriate column 136 from where it is transported to the front of the module 60 for subsequent removal by the operator.

INDEXER

The details of the indexer 100A are shown in more detail in Figures 15 through 20. Referring therefore to Figures 15-20, the indexer 100A includes a

track plate 180 supported on a machine bed 182 and having a dovetail shaped channel 184 formed in the upper surface. The re-entrant walls 186 of the channel 184 are configured to engage the grooves 54,56 formed in the base 22 of the carrier 18 and therefore guide the carrier along the path of the track 180. A stationary wall 188 extends upwardly from the track plate 180 to one side of the channel 184 and is formed with an undercut rectangular recess 190 extending longitudinally parallel to the channel 184. The front face of the wall 188 carries leaf springs 192 arranged in seriatim along the wall 188 and are flexed so as to diverge away from the wall 188 (Figure 19).

A sliding bar 194 is located within the recess 190 and carries a second set of springs 196. The bar 194 may slide back and forth along the recess 190 and is connected by an L-shaped bracket 198 (Figure 18) and connecting rod 200 to a crank wheel 202. The crank wheel 202 is attached to the output shaft of an electrically operated single revolution clutch 204 (Figure 16) that is driven by a belt drive 206 from an electric motor 208 suspended from the machine bed 182 on a bracket 210.

The crank wheel 202, connecting rod and bracket 200,198 are located behind an abutment wall 212 that extends upwardly from the wall 188 opposite the input column 102A. The leading edge of the wall 122 is bevelled as indicated at 214 to provide a lead-in ramp for containers 18 transferred from an adjacent module. The wall 212 also forms as a positive stop for carriers 18 delivered from the input column 102A to allow proper operation of the singulator 104A.

The indexer 100A moves the carriers 18 along the track 184 by reciprocation of the bar 194 in the recess 190. The motor 208 drives the crank wheel 202 through the single revolution clutch 204 which is operated by control signals to terminals 216 (Figure 15A) on the clutch 204 that receive electrical signals from a

central control board for the sorter. Input to the control board is provided by a pair of photosensors 216 (Figure 17) that are carried by the abutment wall 212 and are positioned to be shielded by a shutter 218 carried by the bracket 198.

To advance a carrier 18 on the indexer 100A, a control signal is provided to the clutch 204 that causes rotation of the crank wheel 202 and forward movement of the bar 194 within the recess 190. The spring 196 engages the carrier 18 to move it forward past the next fixed spring 192 which deflects as the carrier 18 moves along the track 180. Once the carrier 18 is beyond the spring 192, the spring 192 resumes its free body position and engages the rear face of the base 20 to prevent reverse motion. The bar 194 then returns under the action of the crank wheel 202 past the adjacent following carrier, if any, until one revolution of the crank wheel 202 is complete. At that time, the shutter 218 blanks the sensors 216 providing a control signal to the controller indicating that one increment of advance has been completed. The clutch 204 is then de-energized until the carrier is to be incremented again. In this way, it will be observed that the indexer 100A advances in a controlled incremental manner the carriers in the track 180 and through use of the electric clutch 204 can delay further actuation until such time as other manipulations on the carrier have been completed.

SINGULATOR

As noted above, the carrier 18 may be introduced to the indexer 100A by means of the singulator 104A that is best seen in detail in Figures 26 through 30. Carriers 18 are delivered to the singulator 106A by the input column 102A which, as seen in Figures 15A and 27, comprises an endless belt 220 entrained around a pair of rollers 222. The belt 220 conveys the carriers 18 to a location between a sensing block 224 located adjacent

the indexer 100A. The block 224 includes a pair of photoelectric sensors 226 located on the opposite side of the belt 220 to a pair of LEDs 228 mounted in a block 230. The sensors 226 sense the presence or absence of a container 18 and provide an appropriate control signal to the sorter control.

Block 224 also carries an additional sensor 232 that monitors the presence or absence of a container 18 in the index track 100A and provides an appropriate control signal to the controller for the sorter module to determine which of the containers 18 to advance.

Assuming that the container 18 at the lead of the input column 102A is to be discharged onto the indexer 100A, the carrier 18 is advanced into the path of the track 184 by continued movement of the belt 220. It will be noted that the nesting of the carriers 18 ensures that each of the carriers 18 is orientated so that the grooves 54,56 are aligned with the re-entrant walls 186 as it is advance. It will of course be understood that the outboard wall 186 of track 180 is interrupted adjacent to the conveyor 220 to allow the container 18 to advance into contact with the abutment wall 212.

With the container 18 advanced, a singulating wedge 234 (Figure 28) that is located between the sensor block 224 and track 180 is moved in a direction parallel to the indexer track and between the tubular bodies 26 of adjacent carriers 18. The wedge 234 is advanced apex first between the bodies 26 by a vertical arm 236 that projects upwardly from a cam following plate 238. The plate 238 slides on a pair of guide rails 240 and has a central rectangular aperture 242 that encompasses a circular cam 244. The cam 244 is mounted eccentrically on a shaft 246 carried between the sidewalls 248 of a housing 250. The shaft 246 is driven by a belt drive 252 from the output shaft of a single revolution electrically controlled clutch 254 that is mounted between the side plates 248. The clutch 254 is driven by an electric

motor 256 mounted on the side plates 248. Upon a signal being provided to the clutch 254 to advance the wedge 234, the motor operates through the clutch 254 to rotate the cam 244 through one-half rotation. One-half rotation of the cam 244 causes the plate 238 to move along the guide rails 240 and carry the wedge 234 between the tubular bodies 22 of adjacent carriers. This action separates the rectangular bosses 40,52 from the slot 26 in the following carrier 18 and provides a single container onto the indexer 100. The wedge 234 is then held in the extended position to inhibit further advance of the containers on the input column 102A. The separated carrier 18 advanced by the indexer 100A upon application of an appropriate control signal to the indexer 100A.

Control signals for the operation of the motor 256 are provided by sensors 258 carried on the housing 250 and shuttered by movement of the arm 236. A control signal is provided to the sorter control indicating a successful separation of the container 18 from the input column 102A to allow further operation of the indexer 100A.

When the control determines that a further container should be dispatched from the column 102A, the clutch 254 is energized to rotate cam 238 a further half-revolution and retract arm 236 and wedge 234. The column of containers 18 will then be advanced by belt 220 to move the next container against abutment wall 212.

If preferred, belt 220 could be moved by a stepping motor under the control of the sensors 226 to regulate advance to the containers 18. As an alternative to the single wedge 234 it is possible to use a pair of wedges on opposite sides of the belt 220 and moveable toward and away from one another by respective cams.

BAR CODE READER

The manipulation of the tube 16 is determined by the data encoded on the label 58. In order to determine the appropriate manipulation of the tube 16 as it is advanced along the indexer 100A between modules, it is necessary to read the label 58 to identify the particular tube 16 and therefore the appropriate manipulation.

The details of the barcode reading station 106A are shown in further details in Figures 21-24. To ensure that the label 58 can be read at the barcode reading station, use is made of the ability of the tube 16 to rotate within the carrier 18. The barcode reading station includes a barcode scanning device 270 carried on a housing 272 mounted above the machine bed 182 adjacent the indexer 100. The scanner 270 projects a fan of light toward the carrier 18 when it is at the barcode reading station so as to impinge upon the slot 28 which is orientated towards the scanner. The tube 16 is rotated within the carrier 18 by a roller assembly 274 driven by a drive motor 276 mounted on the housing 272. The roller assembly 274 includes four rollers 278 that are mounted in L-shaped support blocks 280. Each of the blocks 280 carries a pair of rollers 278 in bearings 282 to permit rotation about a vertical axis. The rollers 276 are driven by pulleys 284 from a belt drive 286 that is derived from idler pulleys 288 mounted on the housing 272. The idle pulleys 288 are driven by a belt 290 from the motor 276.

Each of the L-shaped blocks is mounted to the housing on a shaft 292 for limited movement about a horizontal axis. Movement about the shaft 292 is controlled by a solenoid 294 that is connected by a link 296 to the outer of the mounting blocks 280. The blocks 280 are interconnected by spur gears 298 to ensure equal and opposite rotation of the blocks 280 about their shafts 292 upon reciprocation of the solenoid 294.

With the solenoid retracted, the blocks 292 diverge moving the rollers 276 away from one another. As shown in Figure 24, in this position the tube 16 may be advanced by the indexer 100A between the rollers 278. With the tube 16 positioned opposite the barcode scanner 270, the solenoid is released to move the rollers 278 into a parallel position in which they grip the upper portion of the tube 16. The motor 276 is then energized to rotate the rollers 278 and cause rotation of the tube 16 within the body 18. As the tube 16 rotates, the label 58 is moved past the slot 26 allowing it to be read by the barcode scanner 270. This enables the particular tubes 16 to be identified and a determination made as to further manipulation and testing of the contents of that tube.

Control signals for the operation of the rollers 278 and solenoid 294 are provided by photosensors 300 carried on the housing 272 and actuated by a shutter 302 carried on the block 280. The photosensors 300 provide an indication of the attitude of the rollers 278 to control operation of the indexer 100 and of the motor 270.

Upon satisfactory reading of the label 58 by the scanner 270, the solenoid 294 is again actuated to spread the rollers 278 and allow further movement of the carrier along the indexer 100A. It will be noted from Figure 25 that the wall 188 and the springs 192 are repositioned adjacent the barcode reader to the opposite side of the track 184 to ensure that the wall 188 does not interfere with operation of the barcode scanner.

SHUTTLE AND PUSHER

After the tube 16 has been identified at the barcode reading station 106A, a determination is made as to whether it will be transported to the next module by the indexer 100A or will be sorted into the one of the output columns 136A. Distribution of the containers 18

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is accomplished using a shuttle 110A and the pusher 164 as most clearly shown in Figures 31 through 36. Referring therefore to Figure 31, the shuttle 110A includes a reciprocal holder 310 that may move at right angles to the track 180. The holder 310 is slidably mounted on a guideway 312 above the machine bed 182. The holder 310 includes a base 314 configured similar to the channel 184 so as to retain the base 20 of the container 18. The holder 310 includes an upper finger 316 which terminates prior to an end plate 318 to define a through passage 320 that snugly receives the tubular body 26 of a container 18. If the container 18 is simply to be advanced along the indexer 100A therefore, the carrier 18 may pass the holder 310 without interference to its normal travel. If however, the container 18 is to be dispatched to the output columns 136A, the holder 310 may advance when the container 18 is located in the passage 320 to carry the container 18 to the pusher 164.

Movement of the holder 310 is controlled by a motor 322 that operates through a single revolution electrical clutch 324 onto a crank wheel 326. The crank wheel carries a pin 328 that engages in a slot 330 in the holder 310 and thus causes reciprocation of the holder 310 upon rotation of the crank 326. As can be seen in Figures 33 and 35, a pair of photosensors 332,334 are provided at opposite ends of the travel of the holder 310 to control operation of the clutch 324. The sensors provide control signals to the central controller of the sorter so as to advance the holder 310 to the pusher 164 and wait whilst the pusher distributes the container 18. Thereafter the holder 310 is retracted to receive the next container 18.

The pusher 164 shown in Figures 36 and 37 includes a clamping head 340 that is slidably mounted on a pair of guide rods 342. Movement of the clamp head 340 along the guide rods 342 is provided by a belt drive 344 shown in Figure 15, and driven by a stepper motor to

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carry the clamp head 340 along the guide rods 342 into alignment with an appropriate one of the output columns 136A. The clamping head 340 includes a pair of tongs 346 that are pivoted on shafts 348 to a body 350. The lower end of the tongs 346 carry neoprene pads 352 that engage the opposite faces of the head 24 to carry it with the clamping head. The tongs are movable between open and closed positions by a toggle linkage 354 controlled by a solenoid 356 that is actuated by a control signal from the central controller. Upon energization of the solenoid 356, the armature of the solenoid 356 is retracted causing the toggle linkage 354 to rotate the tongs 356 about the shafts 348 and move the neoprene pads into engagement with the container 18.

The clamp head 340 is moved by the controller to one of two possible "home" positions on either side of the shuttle 110A. Once the shuttle 110A advances the container 18, the clamp head 340 is moved with open tongues 346 to the central position and the solenoid operated to clamp the head of container 18. Once the container is clamped between the tongs 346, the stepper motor moves the clamp head 340 along the guide rods 342 to the entrance to the appropriate column 136A. The solenoid 356 is de-energized, releasing the tongs 346 and allowing the clamp head to move away from the container 18 back to the home position adjacent the shuttle 110A. Once the container 18 has been moved by the clamp head, the shuttle 110A may be retracted to receive the next container 18.

INSERTION BARS

The container 18 is advanced onto the output column 136A by means of insertion bars 166,168 that are positioned below the clamp head to engage the tubular body 26 of container 18. As can best be seen in Figures 20 and 31, the insertion bars are mounted on a pair of vertical fingers 360 that project upwardly from a pair of

spaced horizontal arms 362. The arms 362 are interconnected by a frame member 364 that is slidably mounted on a pair of spaced guide rods 366. The guide rods are secured to the machine bed 182 by blocks 368. The frame member 364 is connected through a web 370 to a parallel frame member 372 that is also slidably received upon the guide rods 366. Reciprocation of the frame 364 on the guide rods 366 is provided by a drive bar 374 that projects through the machine bed 182 and onto a crank connected to the output shaft of a single revolution electrical clutch driven by a drive motor 376 (Figure 15). Upon energization of the clutch, the motor causes the frame 364,372 to slide along the guide rods 366 and advance the pusher arm 166,168 and move the container 18 into the output column 136A.

The container is carried along the output column 136A by an endless belt 380 driven by a drive shaft 382. Drive to the drive shaft 382 is provided by a chain drive 384 (Figure 20) from a drive motor 386. Discharge of the container 18 from the distal end of the output columns 136A is inhibited by a spring loaded latch finger 390 as shown in Figure 38 which may be depressed by an operator to allow the row of containers 18 to be withdrawn.

To prevent overloading of a particular output column 136A, a signalling device as shown in Figure 39 is provided at the head of each of the output columns 136A. The signalling device indicated at 400 includes a pivoted latch member 402 having a lead-in ramp 404 that is lifted by the protrusion 28 on the base 22 of the container 18. The latch member 402 is formed with a hook 406 to prevent reverse motion of the container in the output column and carries a magnet 408 that operates on a reed switch to provide signal to the central controller. The signal line from reed switch has a built in delay of approximately 2 seconds so that normal passage of the container 18 will lift the latch and allow it to return

without providing a control signal. However, if the column 136A is full, the latch is held in an elevated position to supply a control signal to the panel and either inhibit further operation of the sorter until such time as the column 136A is emptied or to divert the pusher to an adjacent column previously designated for similar segregated tubes 16.

It will be seen therefore that the transport system provides for an orderly passage of containers through the automated testing and allows separation of the nested containers, reliable and accurate reading of the barcode at each station and subsequent manipulation utilizing the characteristics of the container and the tube in an orderly manner. At each stage, signals are provided to the central controller to ensure that each operation is completed in the manner required.

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What is claimed is:

1. A system for transporting blood specimens for processing, comprising:

(a) means for carrying each discrete blood specimen;

(b) a plurality of modules, each for performing a pre-qualitative analysis process upon the specimens, said modules jointly defining a path along which said carrying means move through the system; and

(c) drive means for moving said carrying means from module to module along said path.

2. A system in accordance with claim 1 further comprising transport means for receiving said carrying means for movement through the system.

3. A system in accordance with claim 2 wherein said transport means is provided with a window to expose identifying indicia applied to said carrying means.

4. A system in accordance with claim 1 wherein the system includes at least one sorter module, a centrifuge module, and a module for aliquotting portions of a blood specimen in one carrying means into a plurality of carrying means.

5. A system in accordance with claim 4 wherein said modules are serially positioned adjacent one another to define said path along which said carrying means move through the system.

6. Apparatus for sorting a plurality of blood specimens carried in corresponding barcoded specimen tubes received in transport devices having a window to expose barcode information applied to a specimen tube, comprising:

(a) an input column for receiving a nested string of transport devices having specimen tubes received therein, said input columns each having a feed end and a singulation end;

(b) means for moving the transport devices along said input column from said feed end to said singulation end thereof;

(c) means for singulating a lead transport device presented at said singulation end of said input column, from the nested string of transport devices;

(d) first conveyor means intersecting said input column proximate said singulation end thereof, said first conveyor means including, along a length thereof, a station at which barcode information applied to a specimen tube is read;

(e) a plurality of output columns; and

(f) means for depositing transport devices into one of said output columns depending upon barcode information read at said station.

7. Apparatus in accordance with claim 6 wherein said means for moving the transport devices along said input column from said feed end to said singulation end thereof comprises a belt drive mechanism.

8. Apparatus in accordance with claim 6 wherein said means for singulating a lead transport device presented at said singulation end of said input column from the nested string of transport devices comprises at least one ramped blade element disposed for movement across said input column for insertion between the lead transport device presented at said singulation end of said input column and a transport device immediately rearward of the lead transport device to effect denesting of said lead transport device from said transport device rearward of said lead transport device.

9. Apparatus in accordance with claim 8 wherein said at least one ramped blade element urges the lead transport device in said input column, after singulation thereof, onto said first conveyor means.

10. Apparatus in accordance with claim 6 wherein said first conveyor means comprises a plurality of generally linearly-aligned, sequentially-adjacent tabs adapted to move along an axis from said singulation end of said input column to said station at which barcode information applied to a specimen tube is read, wherein a forward end of a tab engages a shoulder defined by a transport device in order to convey the transport device from said singulation end of said input column to said station at which barcode information applied to a specimen tube is read.

11. Apparatus in accordance with claim 6 wherein said station at which barcode information applied to said specimen tube is read includes means for rotating the specimen tube, when located at said station, to ensure the barcode information is viewable through the window in the corresponding transport device in which the specimen tube is received.

12. Apparatus in accordance with claim 11 wherein said means for rotating a specimen tube comprises at least one roller, rotatable about an axis, at said station engageable with the specimen tube when the specimen tube is at said station.

13. Apparatus in accordance with claim 12 wherein said roller rotates the specimen tube through approximately 360°.

14. Apparatus in accordance with claim 6 wherein said means for depositing transport devices into one of

said output columns depending upon barcode information read at said station comprises second conveyor means.

15. Apparatus in accordance with claim 14 wherein said second conveyor means extends generally parallel to said first conveyor means.

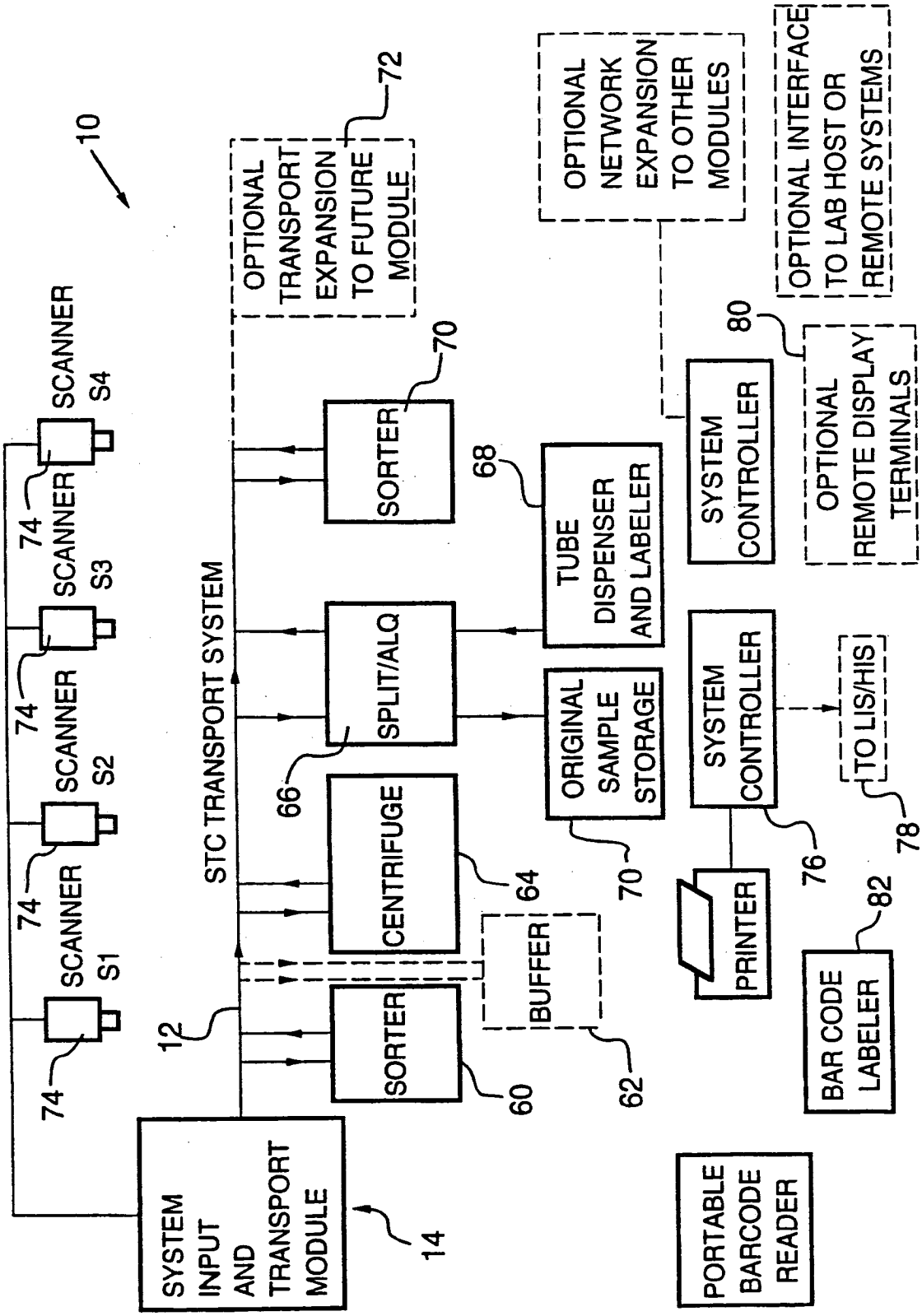

FIG.1.

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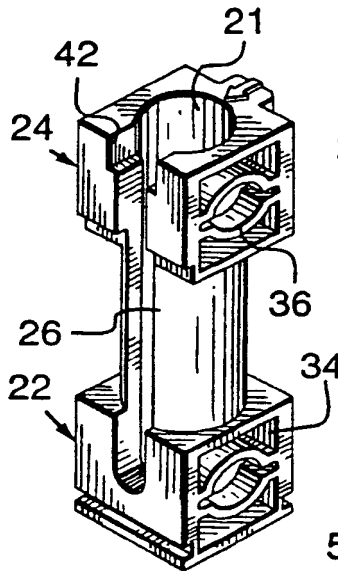

FIG.4.

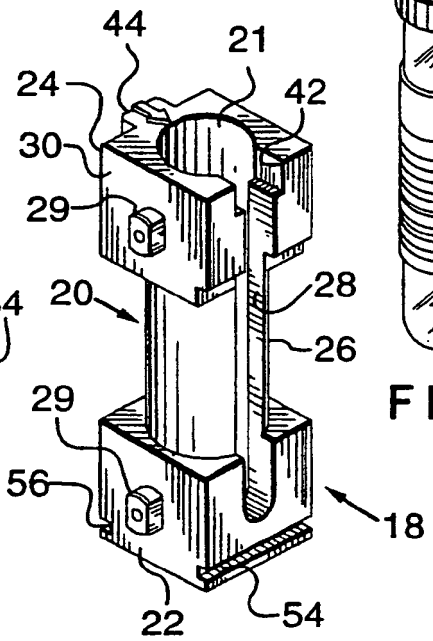

FIG.5.

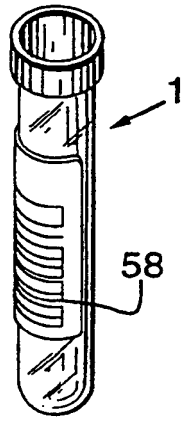

FIG.2.

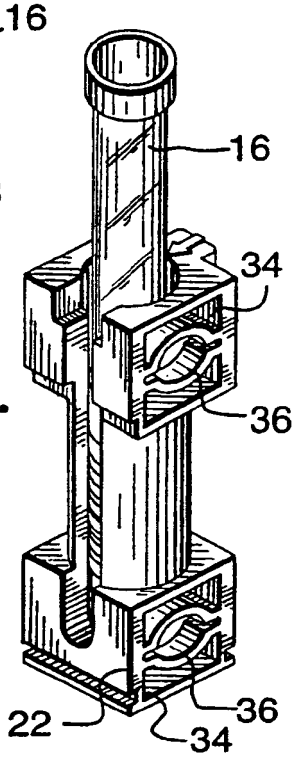

FIG.3.

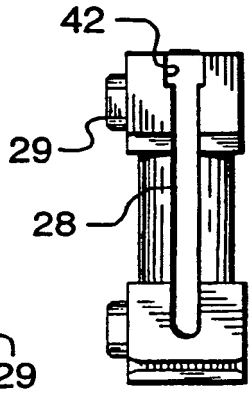

FIG.6.

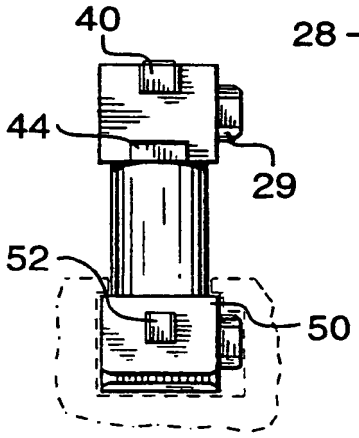

FIG.8A.

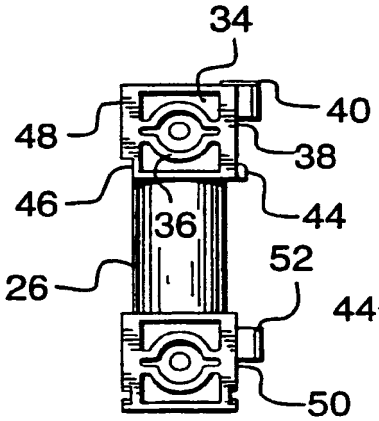

FIG.7.

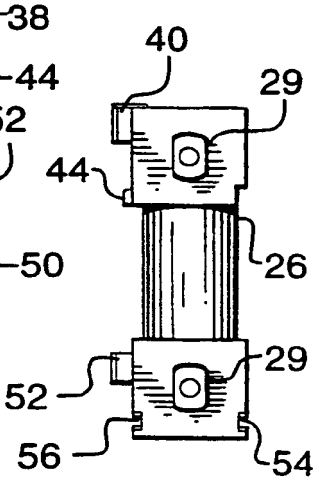

FIG.8.

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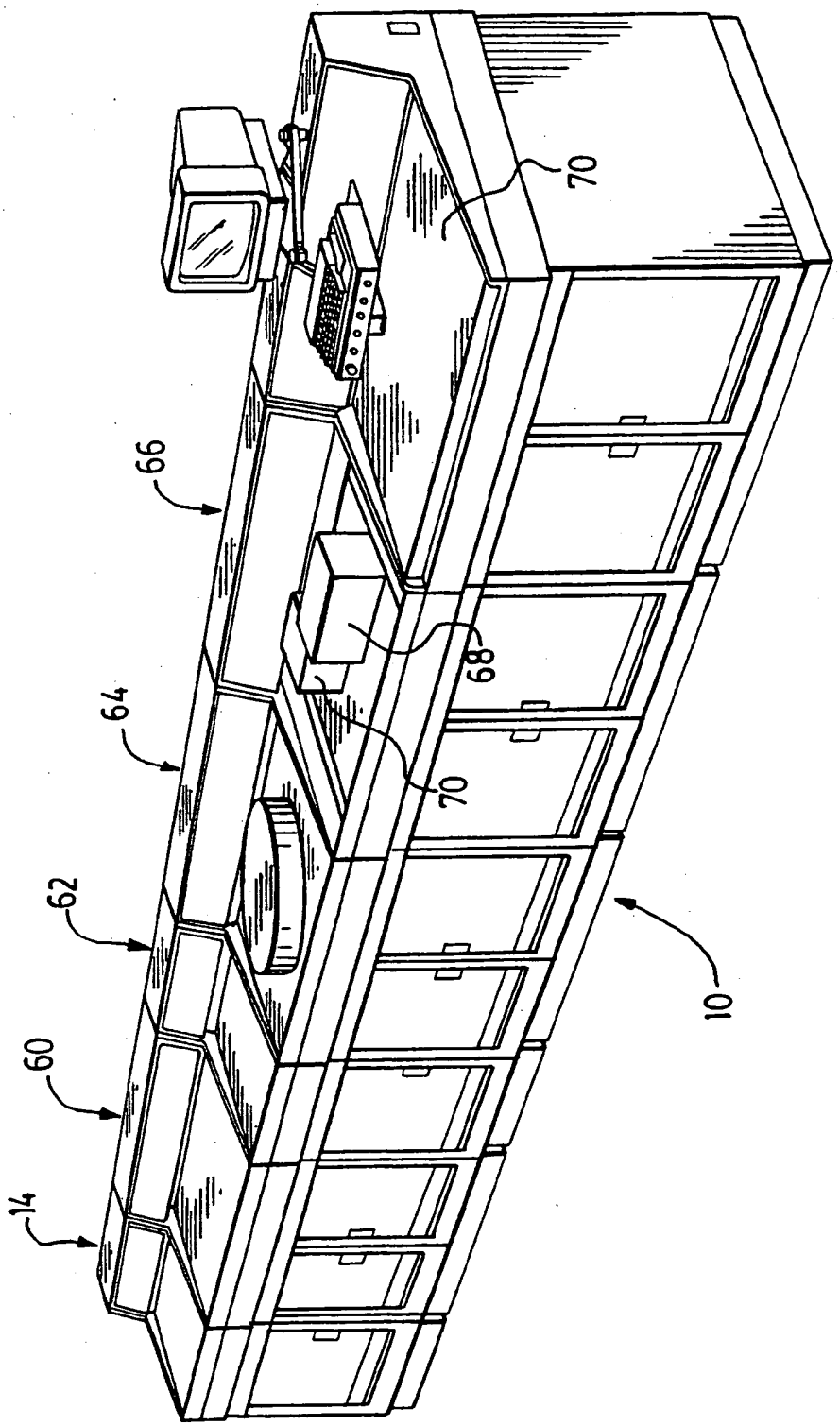

FIG.9.

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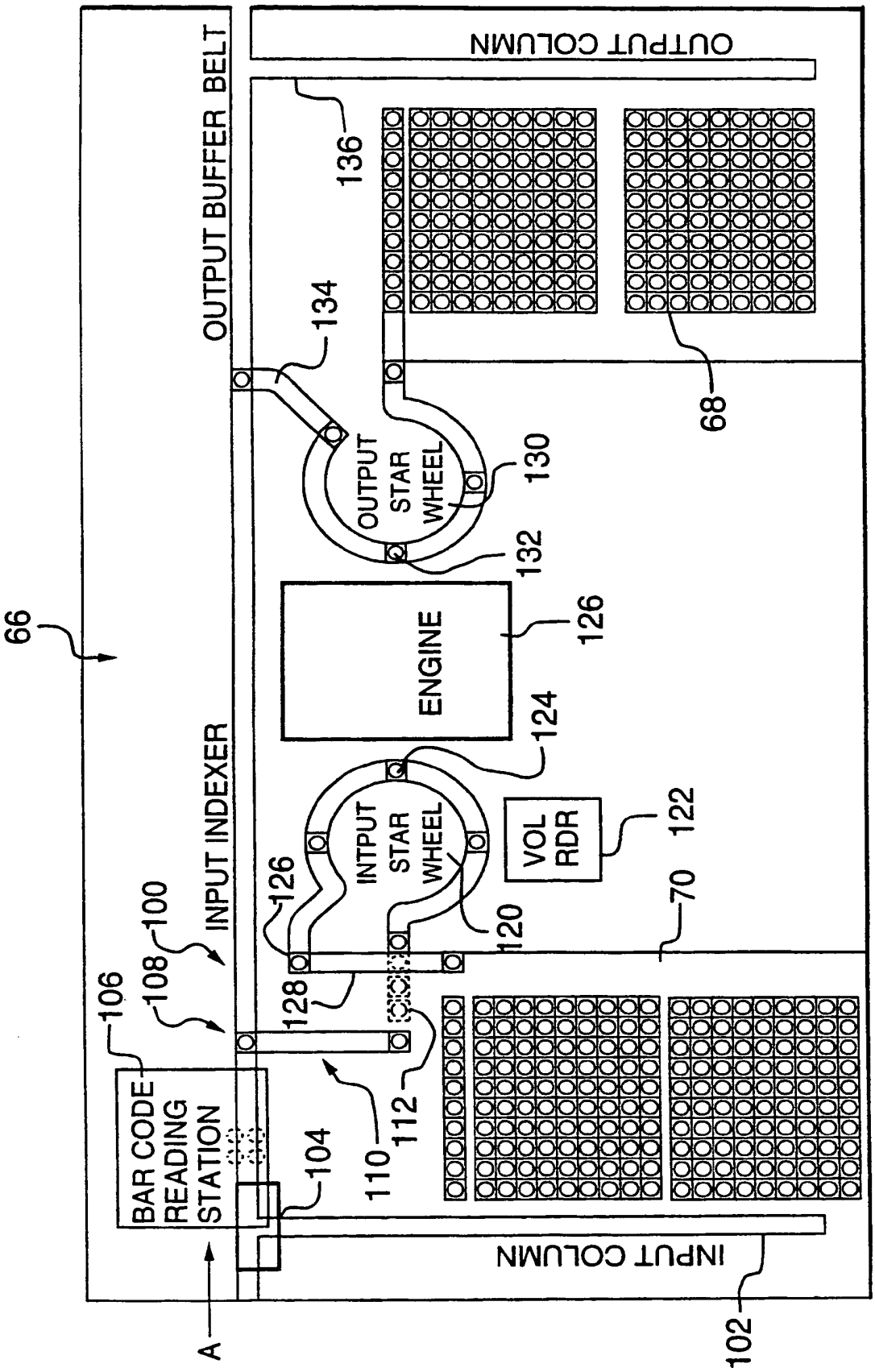

FIG.10.

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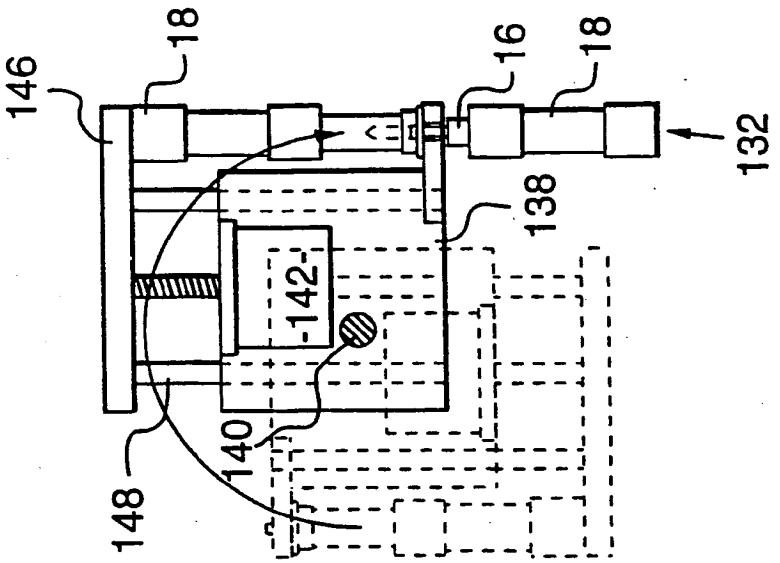

FIG.13.

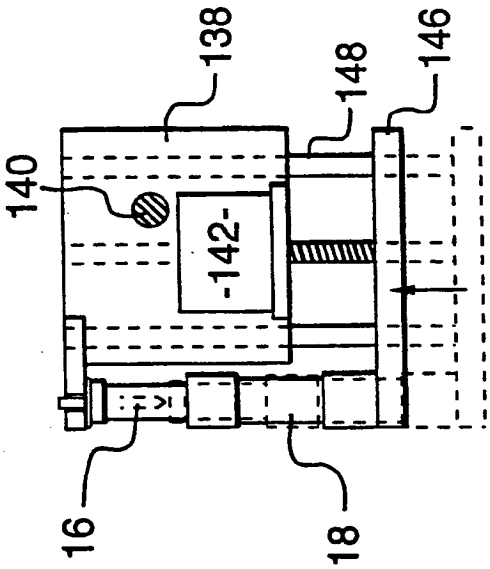

FIG.12.

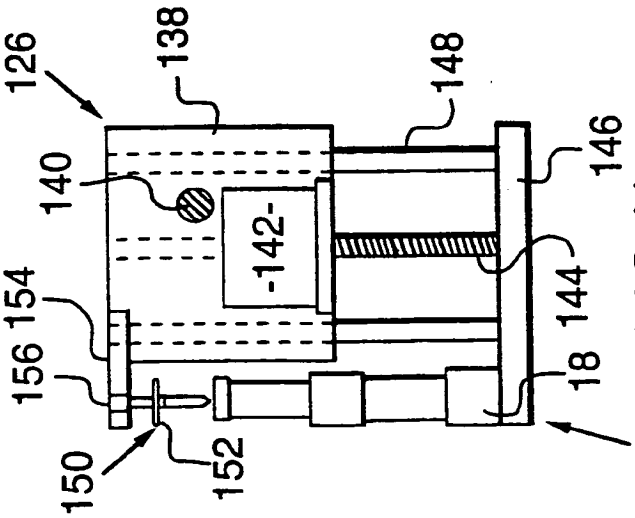

FIG.11.

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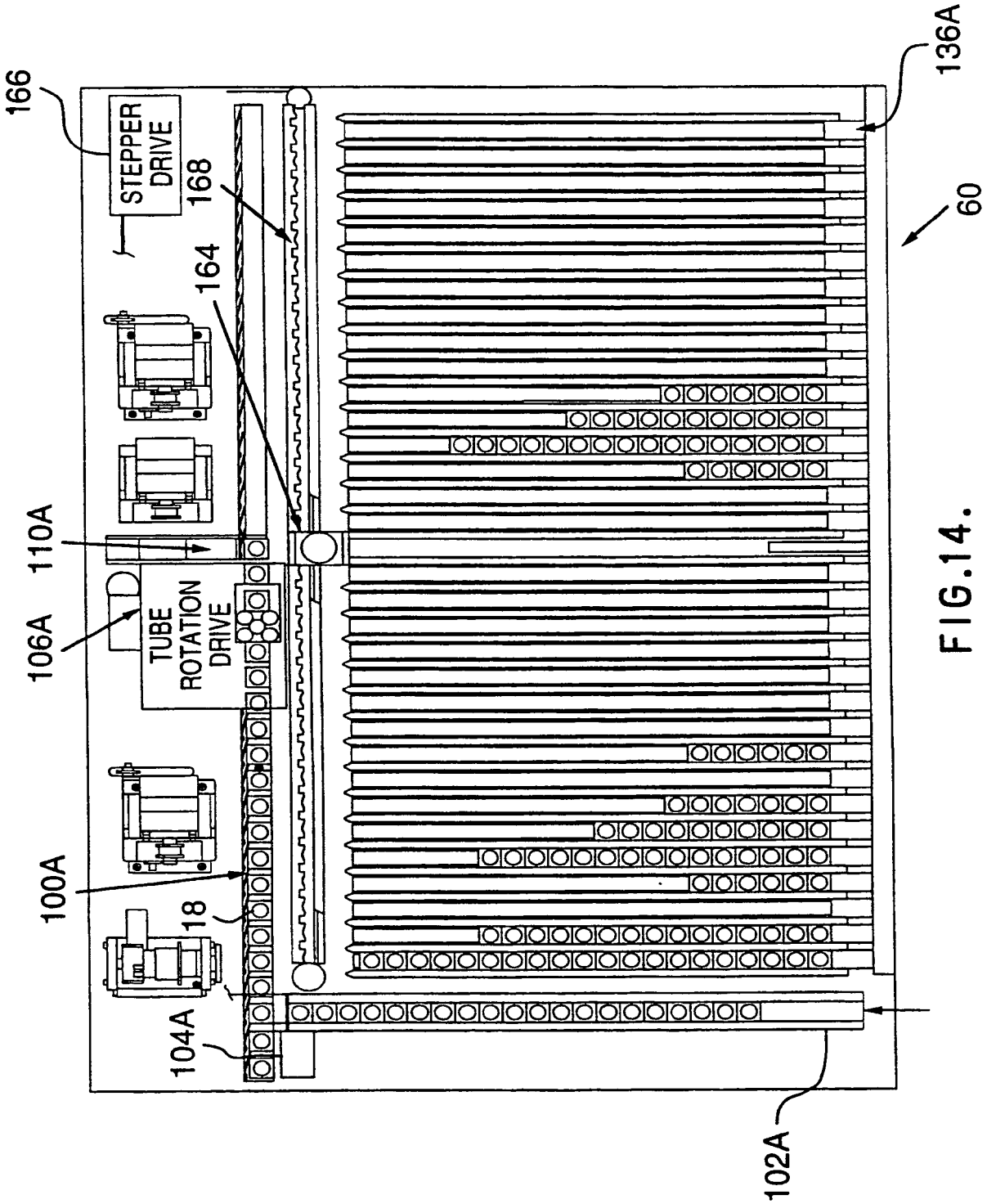

FIG.14.

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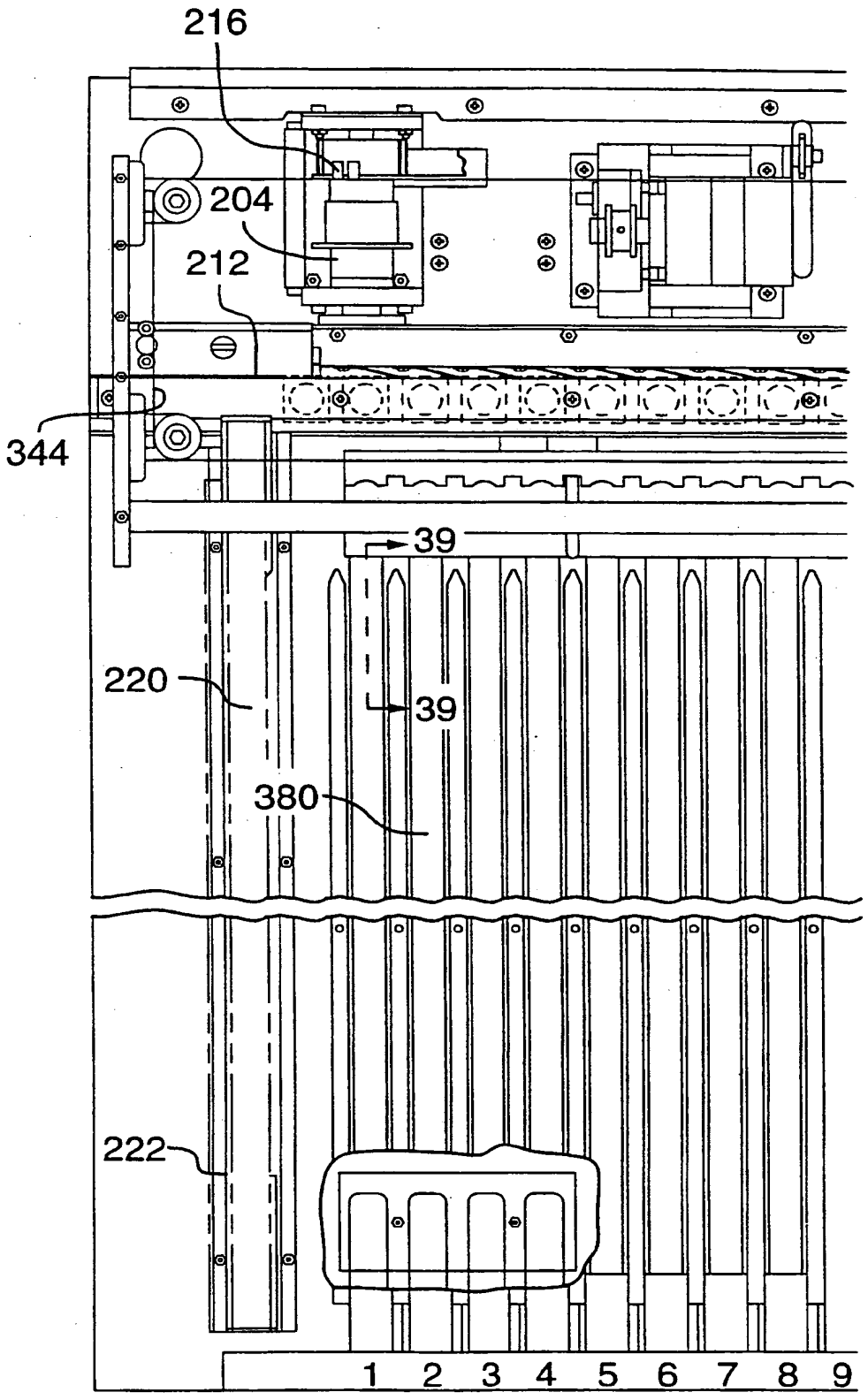

FIG.15A.

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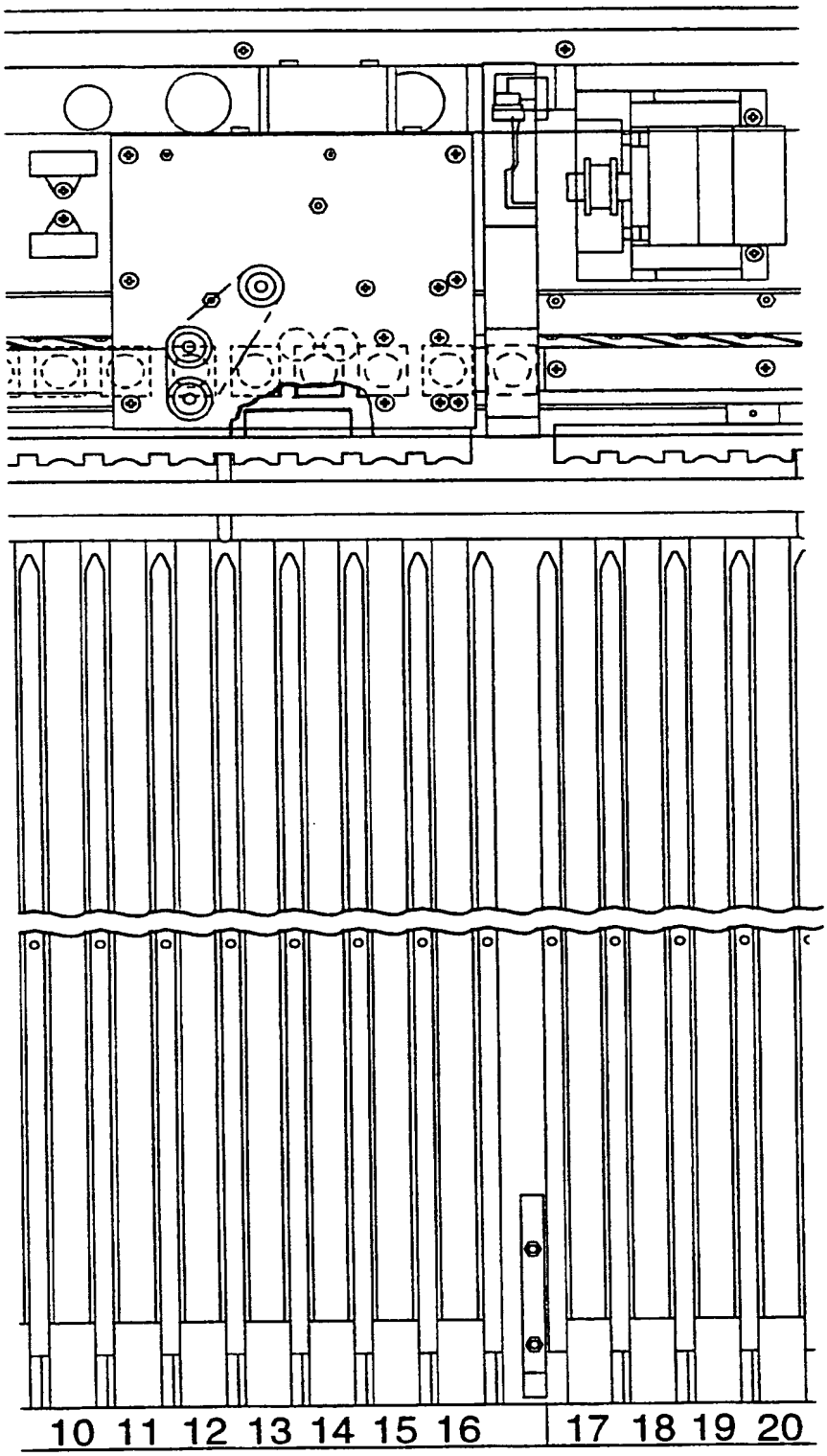

FIG.15B.

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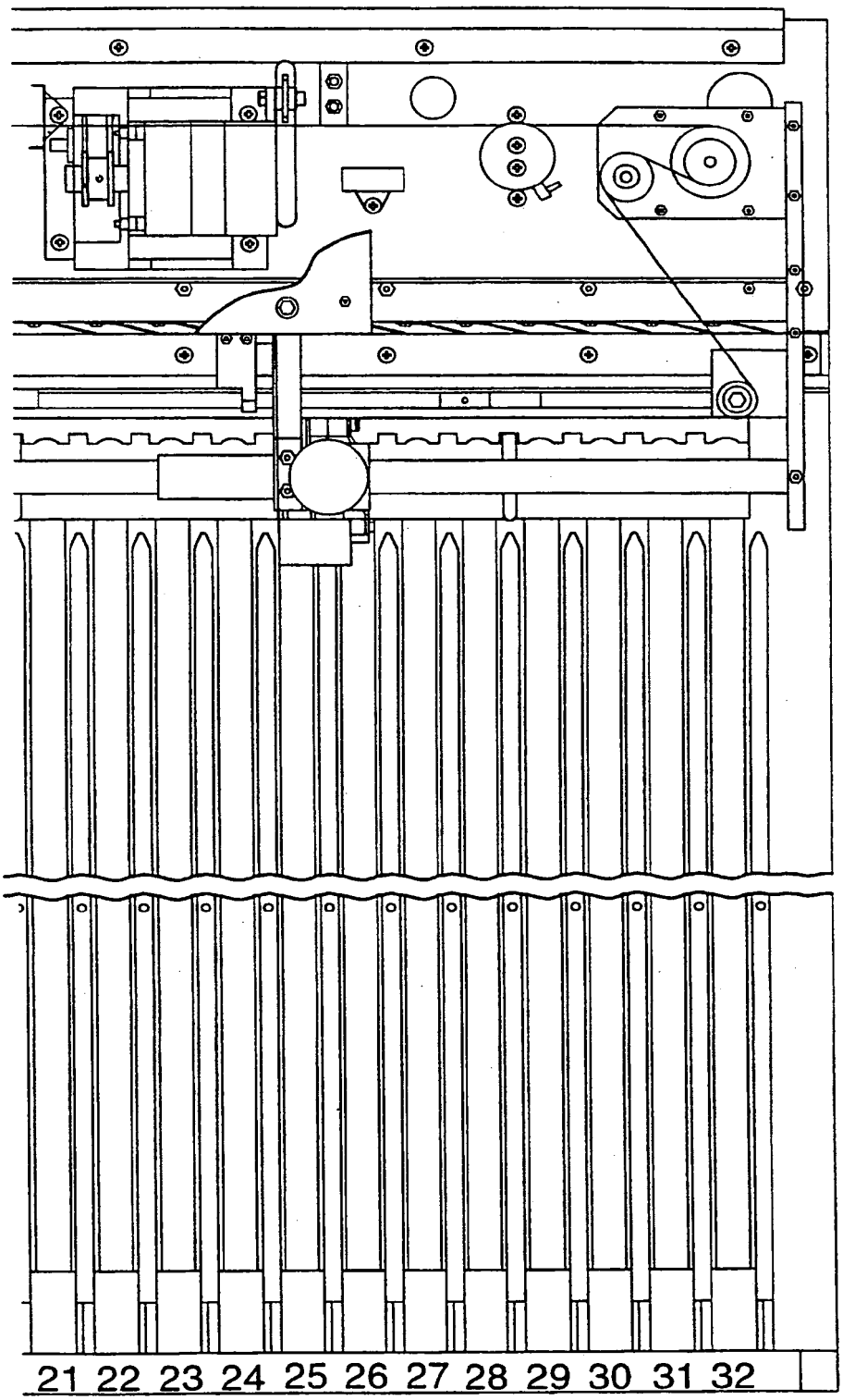

FIG.15C.

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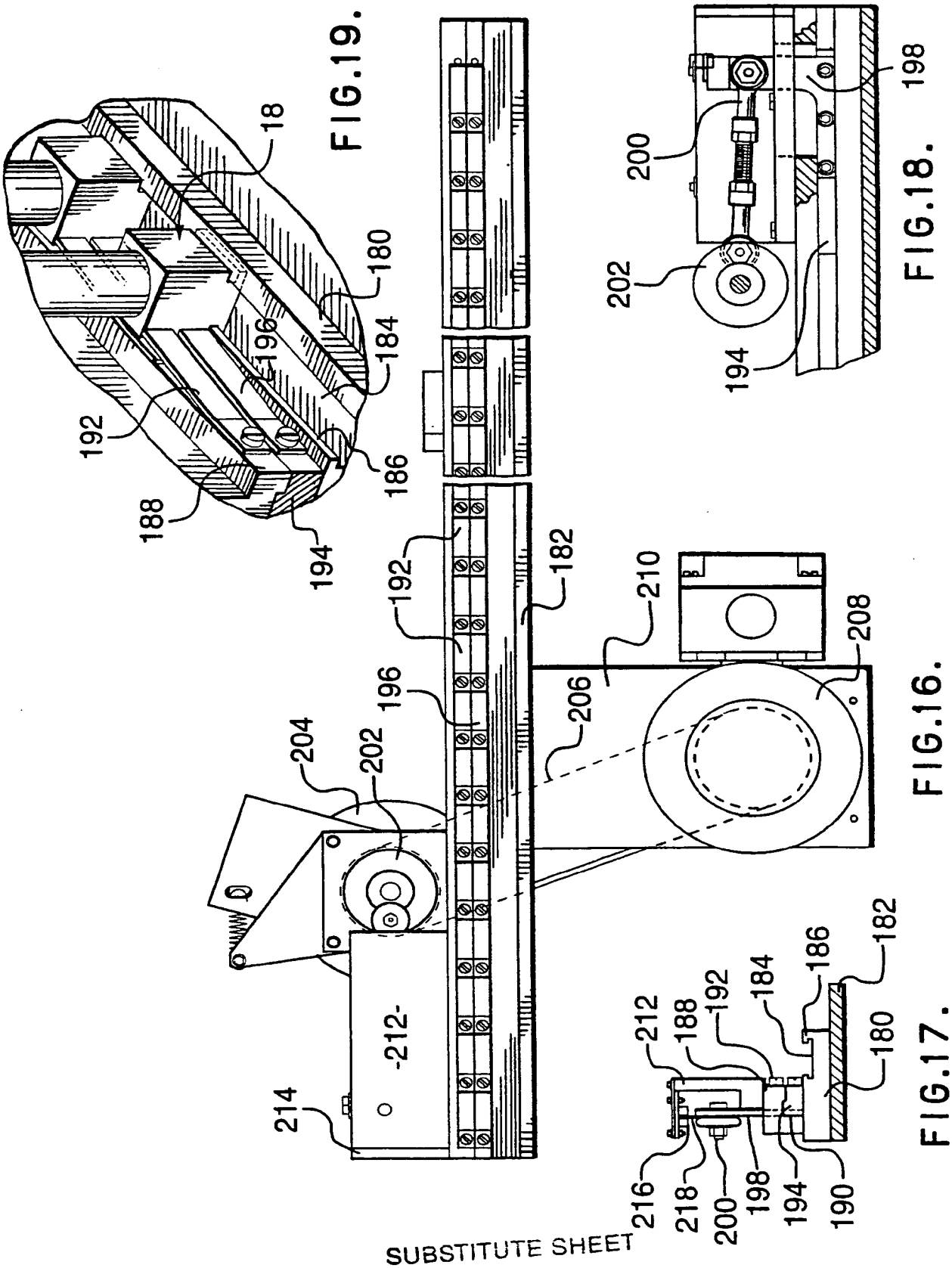
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FIG.19.
FIG.18.
FIG.16.
FIG.17.

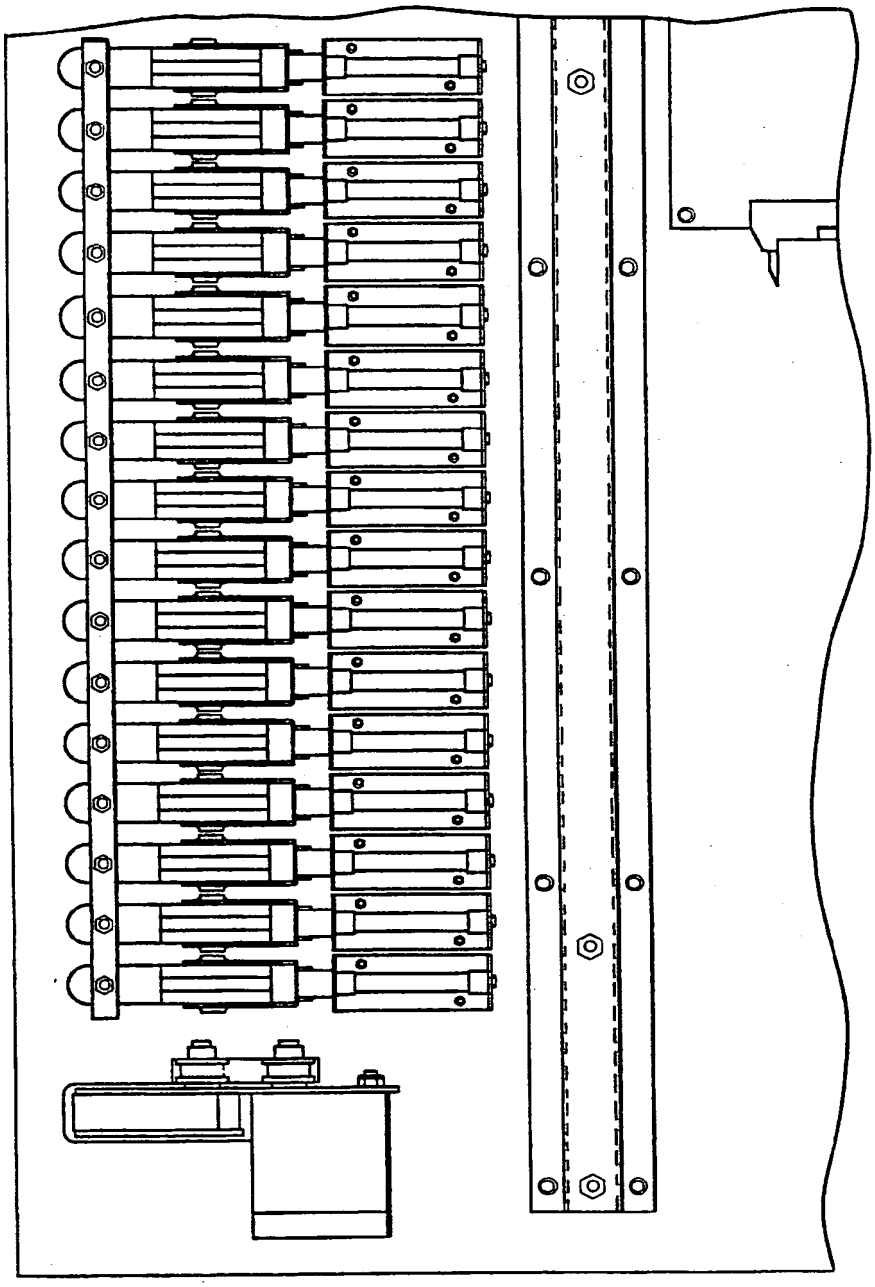

FIG.20A.

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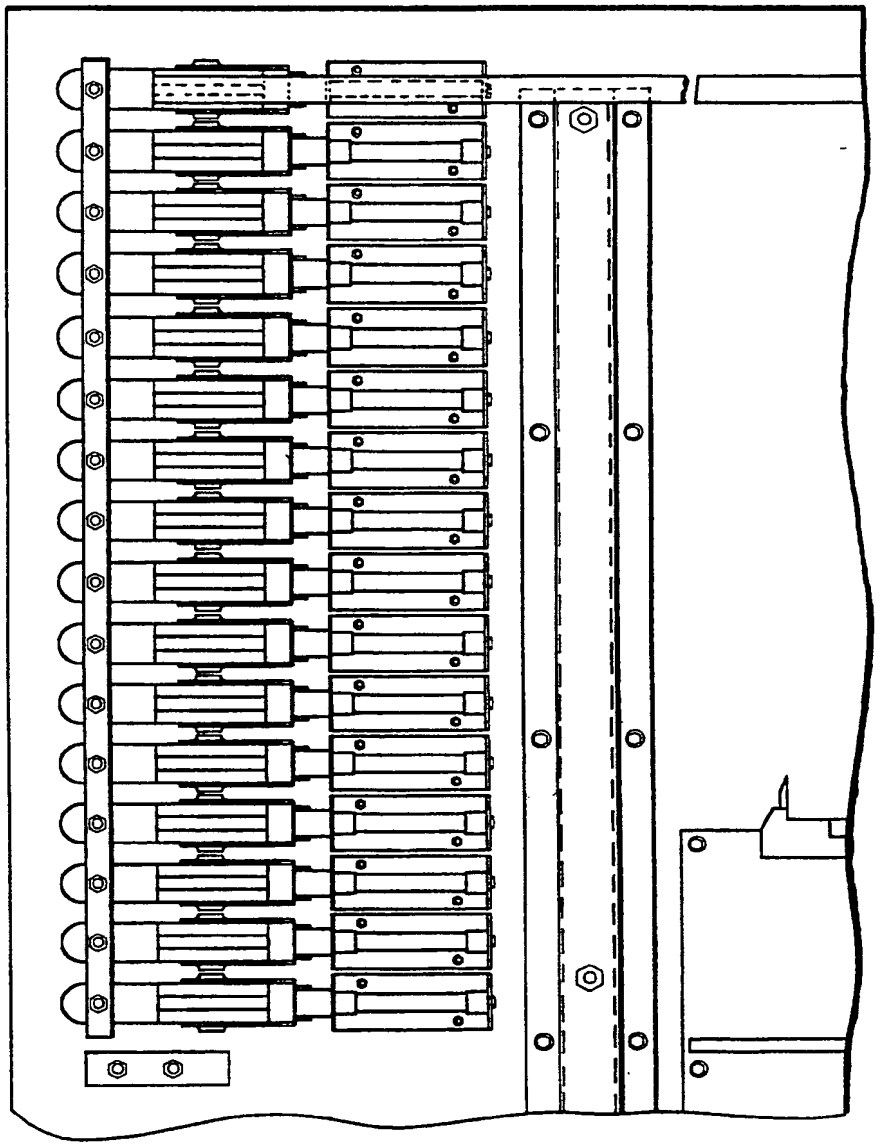

FIG.20B.

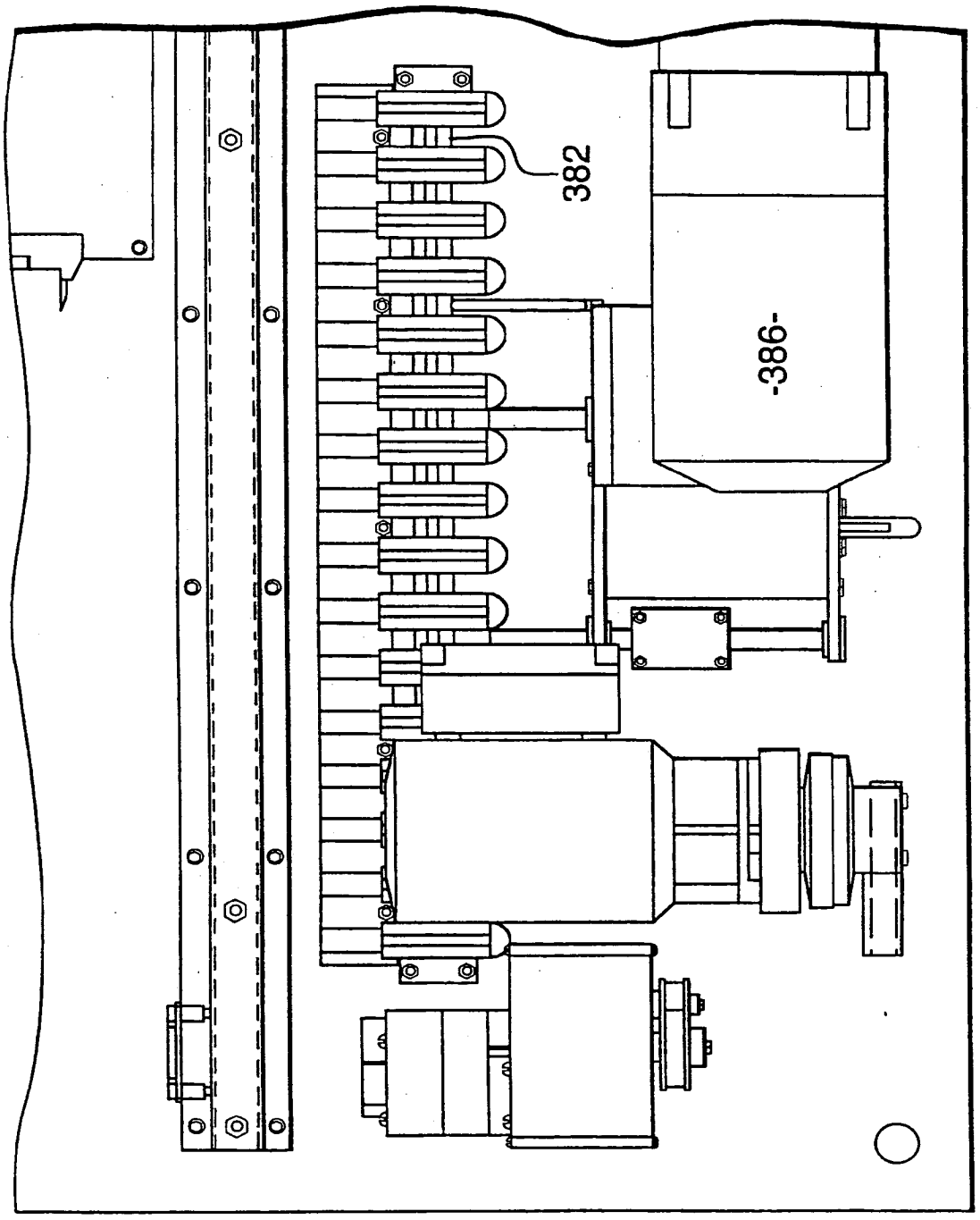

FIG.20C.

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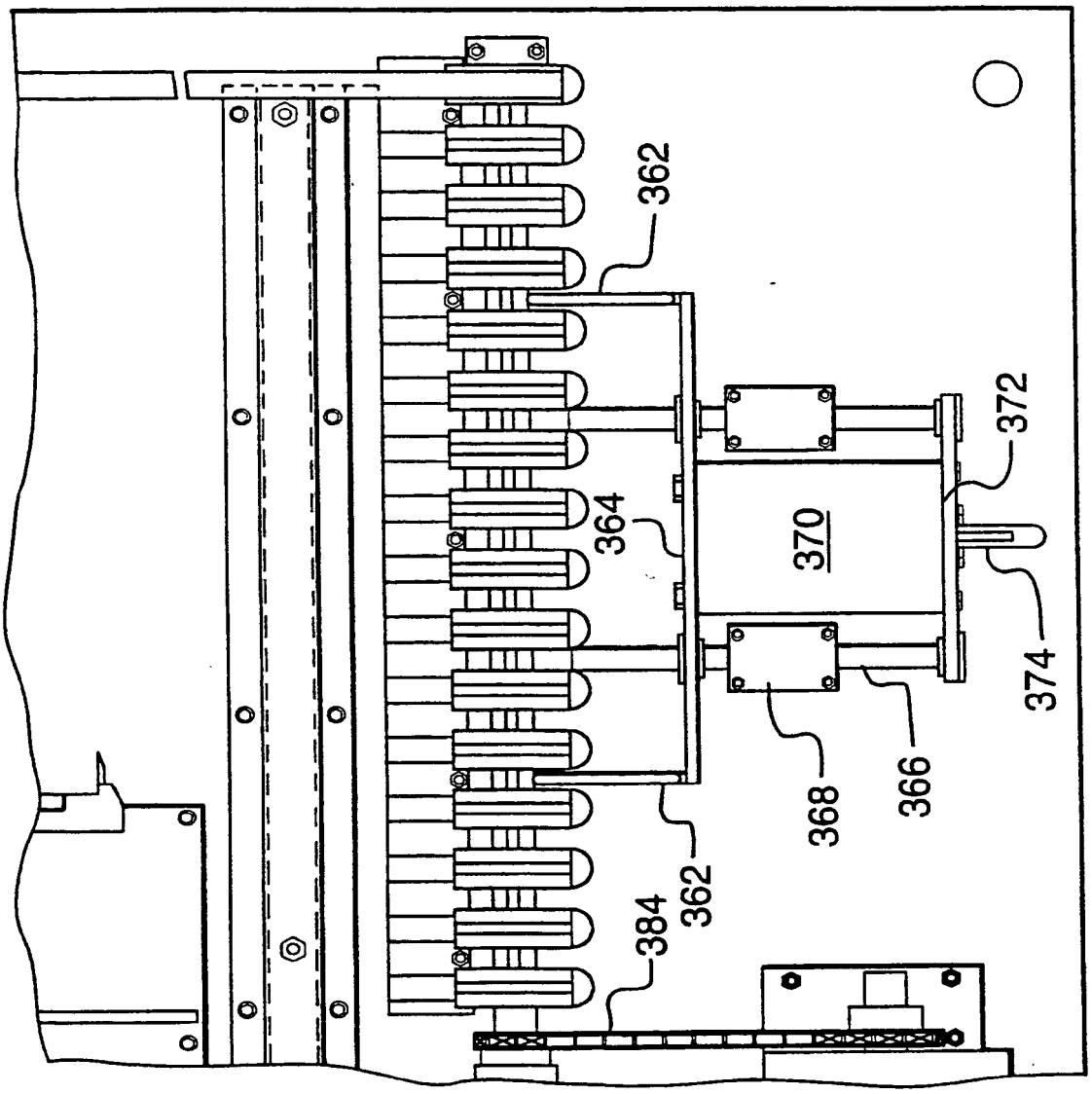

FIG.20D.

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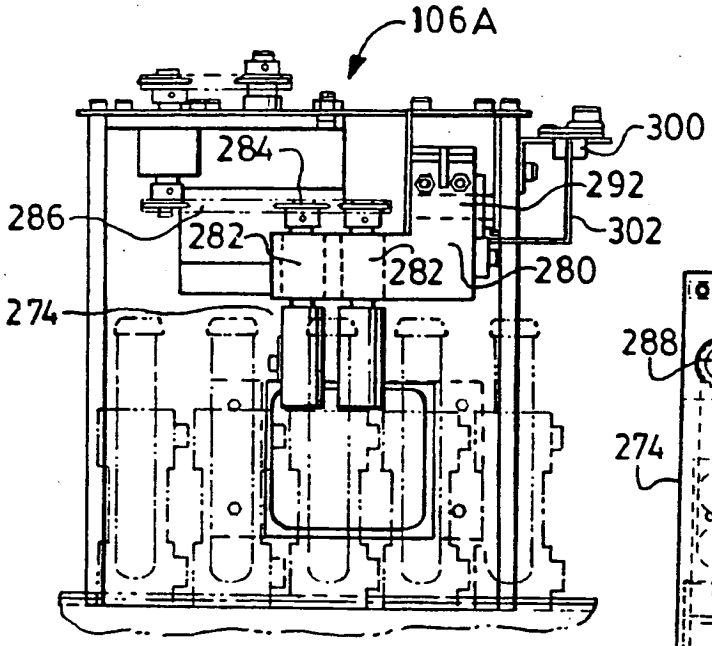

FIG.21.

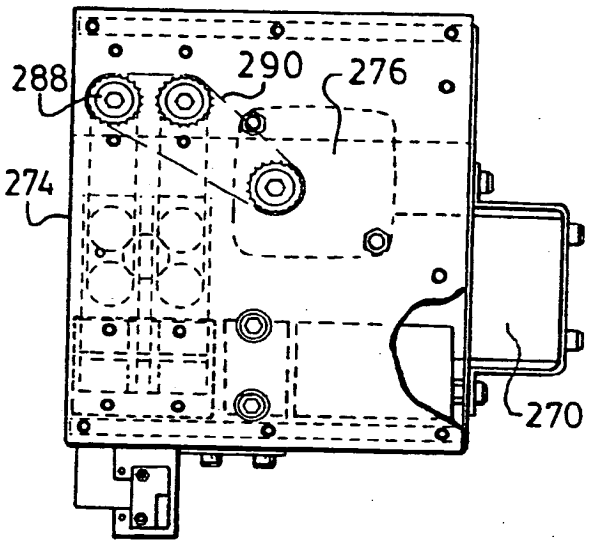

FIG.22.

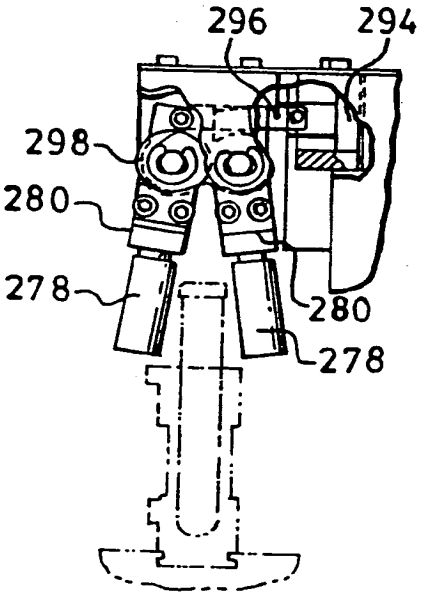

FIG.24.

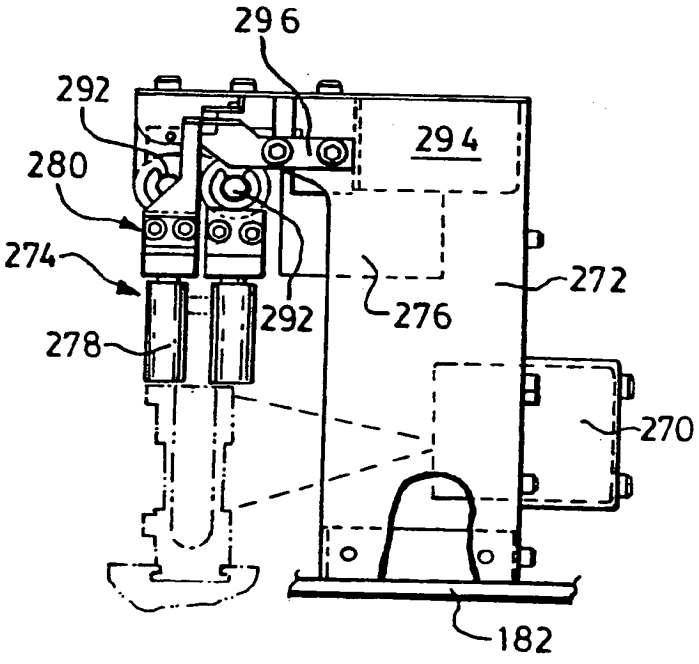

FIG.23.

BNSDOCID: <WO_____9503548A1_I_>

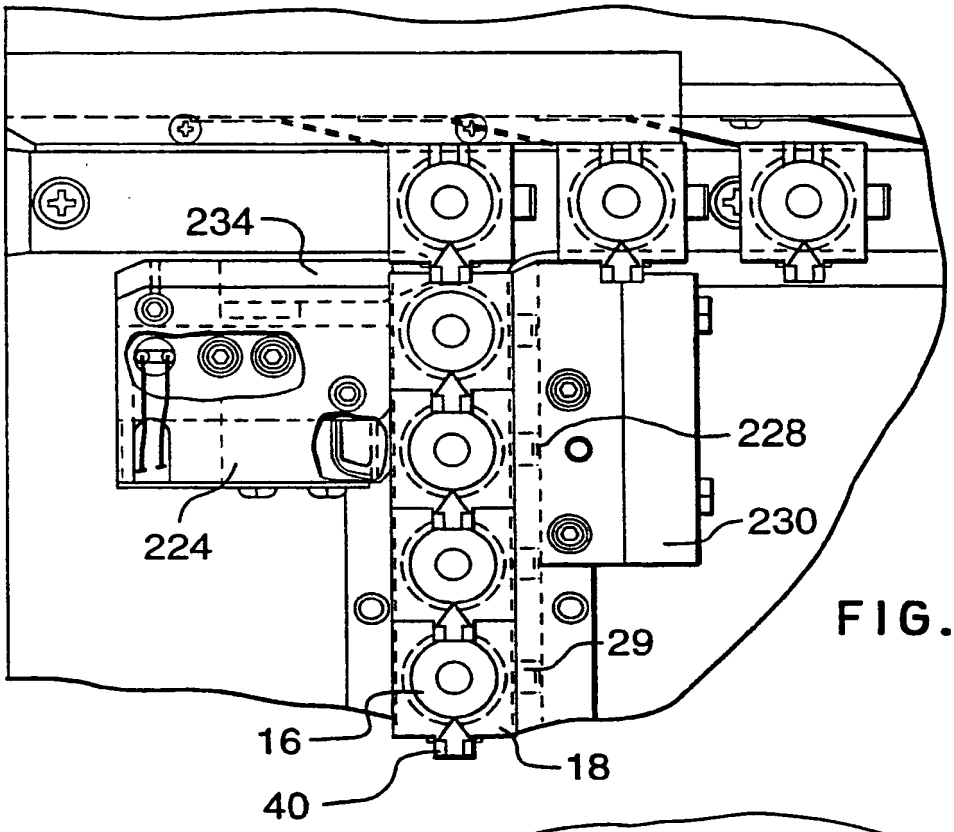

FIG.26.

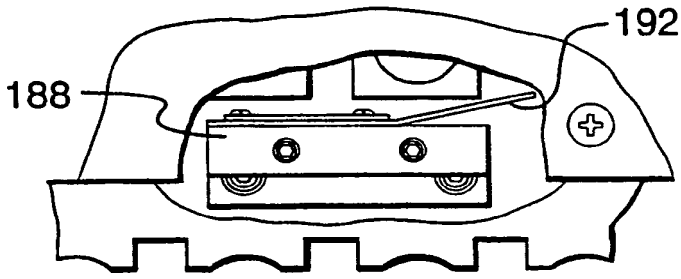

FIG.25.

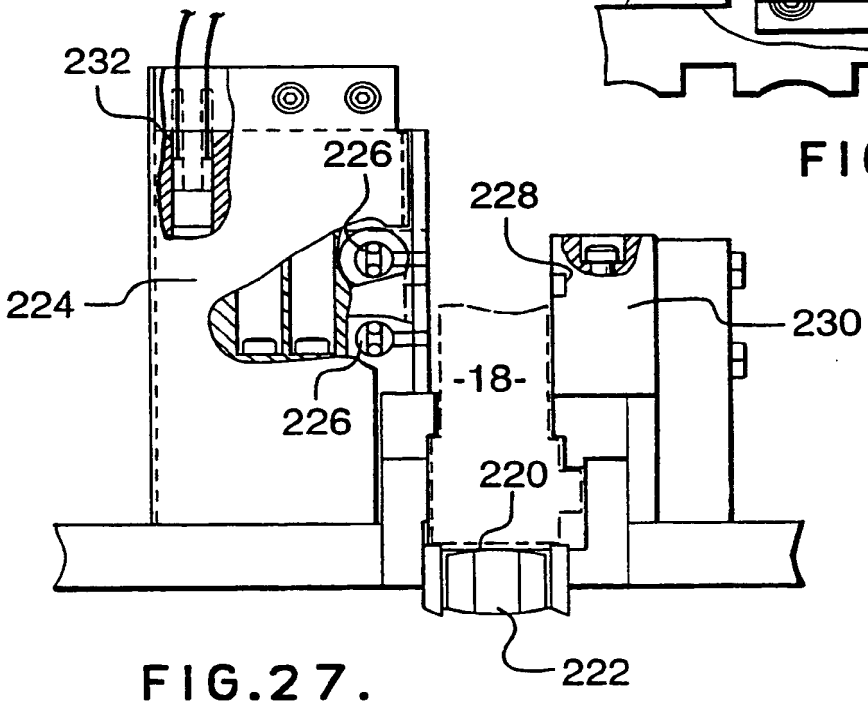

FIG.27.

BNSDOCID <WO 9503548A1 I >

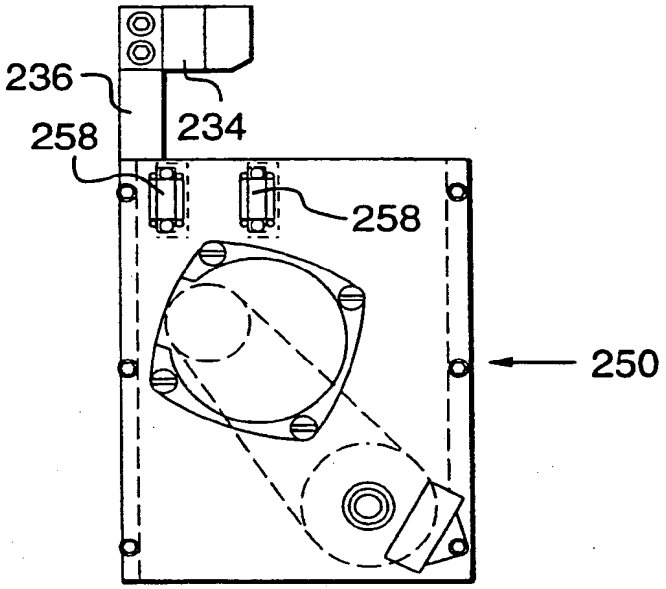

FIG.28.

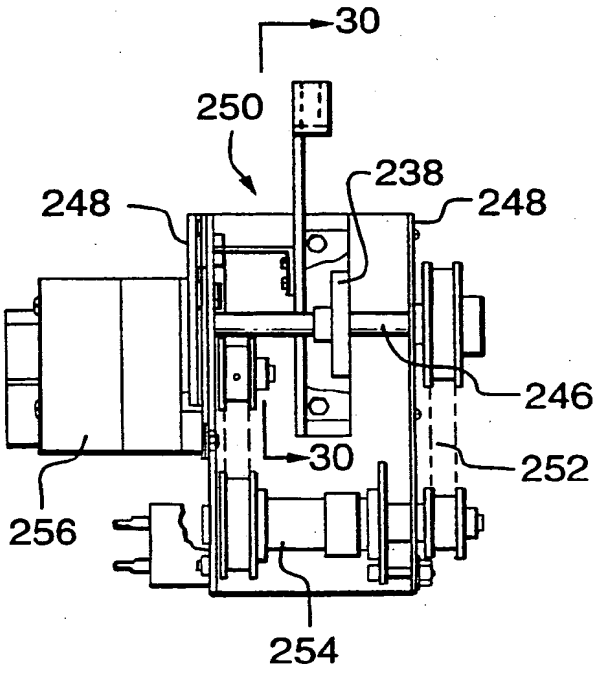

FIG.29.

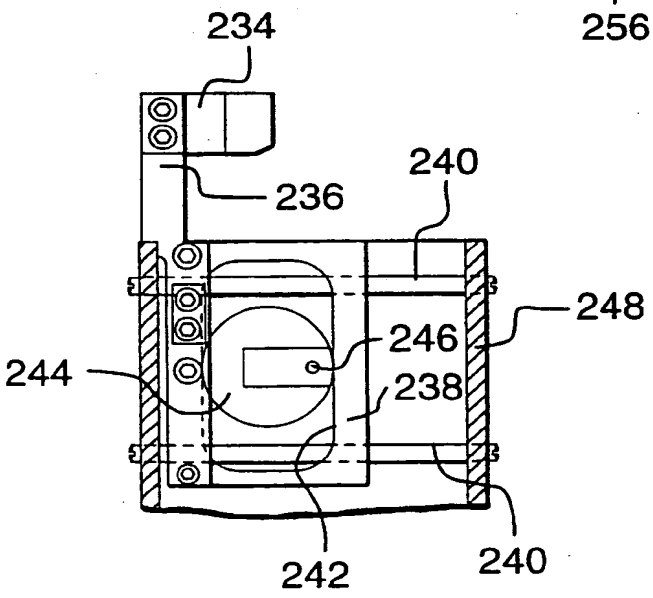

FIG.30.

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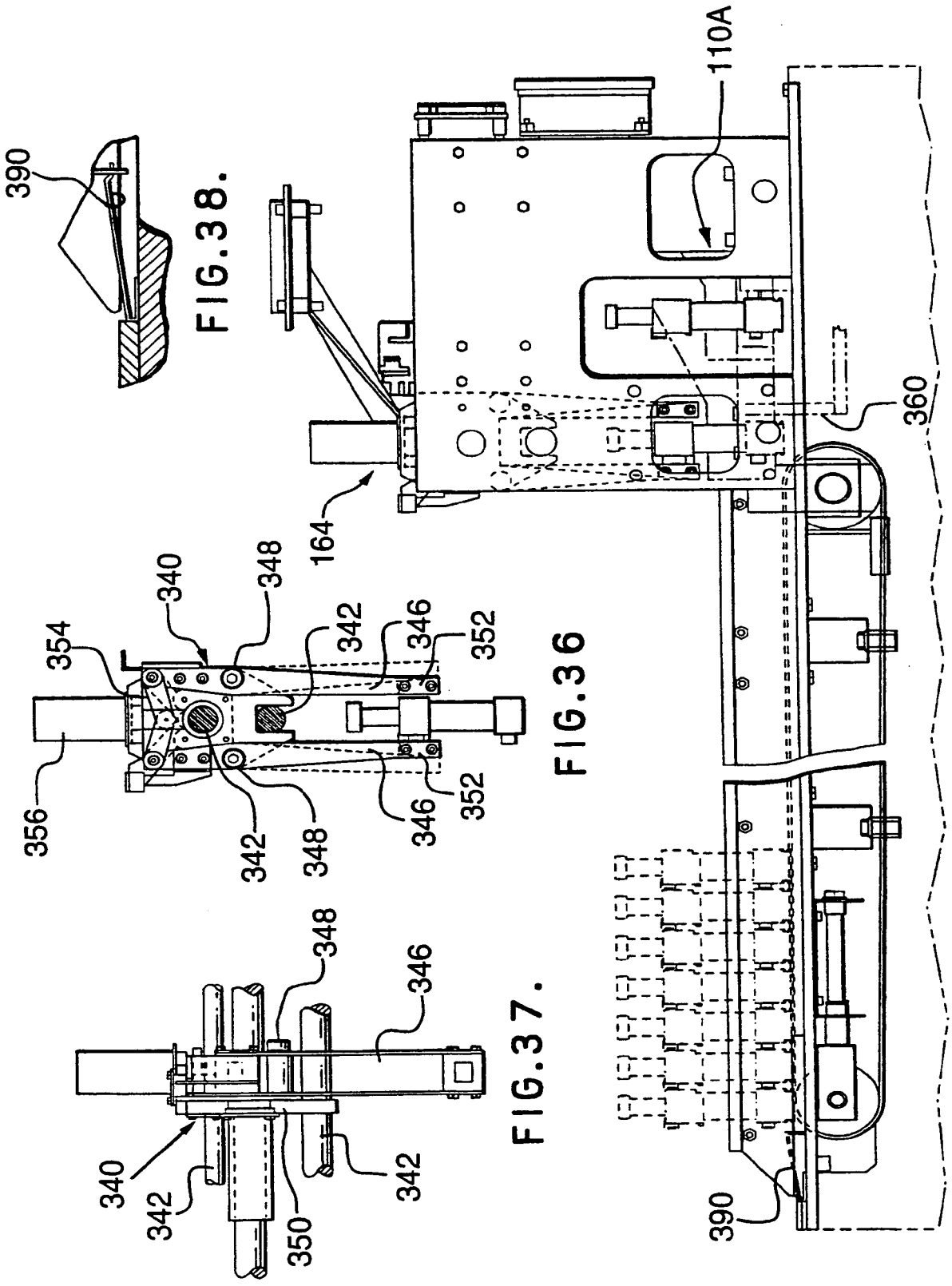

FIG.31.

FIG.36

FIG.37.

FIG.38.

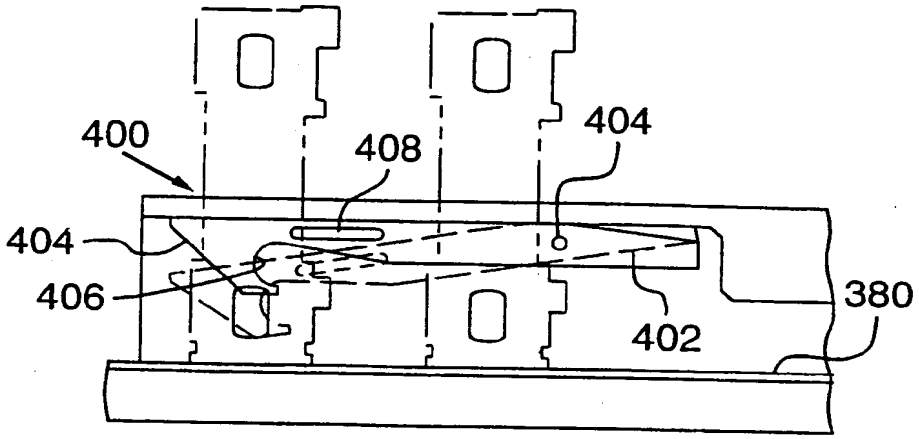

FIG.39.

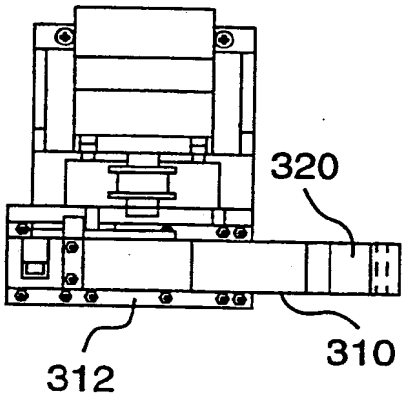

FIG.32.

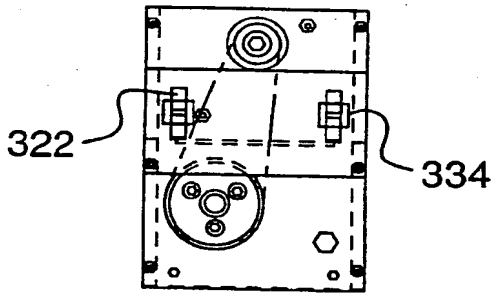

FIG.35.

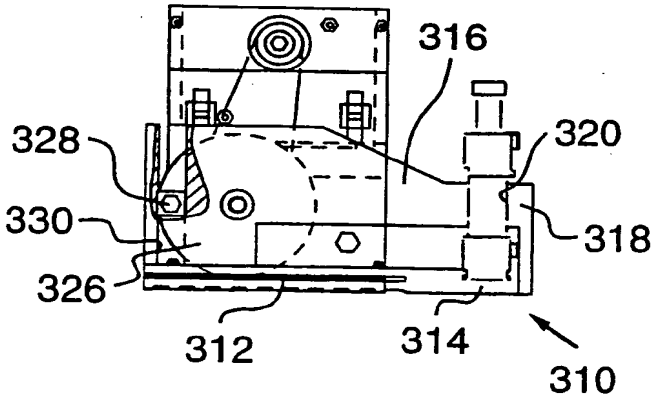

FIG.33.

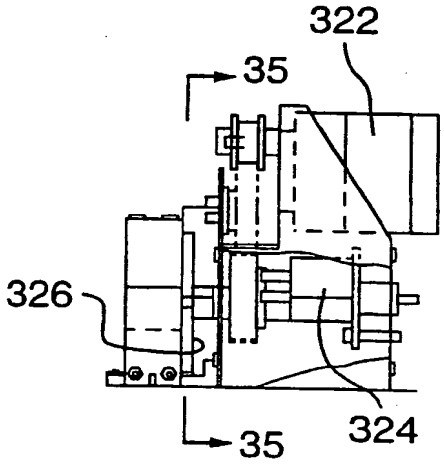

FIG.34.

BNSDOCID: <WO_____9503548A1_I_>

INTERNATIONAL SEARCH REPORT

Int...ational application No.
PCT/US93/06758

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :G01N 35/02, 35/04, 35/06
US CL :422/63, 65, 67, 72, 102, 103, 104; 436/43, 45, 47, 48, 55
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 422/63, 65, 67, 72, 99, 100, 102, 103, 104; 435/809; 436/43, 45, 47, 48, 55

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US, A, 5,008,082 (Shaw) 16 April 1991, see the abstract and summary of the invention.	1-3 4, 5
X Y	US, A, 3,854,879 (Figueroa et al.) 17 December 1974, see entire document.	1-3 4-7, 10-15
X Y	US, A, 4,873,633 (Mezei, Louis M. et al.) 10 October 1989, see Summary of the Invention section and columns 5-7.	1-5 6-7, 10-15
X Y	US, A, 4,861,553 (Mawhirt et al.) 29 August 1989, see columns 1 and 2.	1-3 4-7, 10-15
X Y	US, A, 4,595,562 (Liston et al.) 17 June 1986, see the abstract and figures.	1-3 4-7, 10-15

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be part of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date		
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search 04 October 1993	Date of mailing of the international search report 20 OCT 1993
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. NOT APPLICABLE	Authorized officer LONG LE Telephone No. (703) 308-0196

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US93/06758

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US, A, 4,692,308 (Riley et al.) 08 September 1987, see the abstract and figures.	1-3 4-7, 10-15
X Y	US, A, 3,883,308 (Matte) 13 May 1975, see figures 2-6 and 28.	1-3 4-7, 10-15
A	US, A, 3,350,946 (Isreeli) 07 November 1967, see entire document.	1-15
A	US, A, 3,909,203 (Young et al.) 30 September 1975, see the abstract and figures 5-9.	1-15

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